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The Digest
OF
Physical Tests
AND
Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

JOSEPH W. BRAMWELL, EDITOR.

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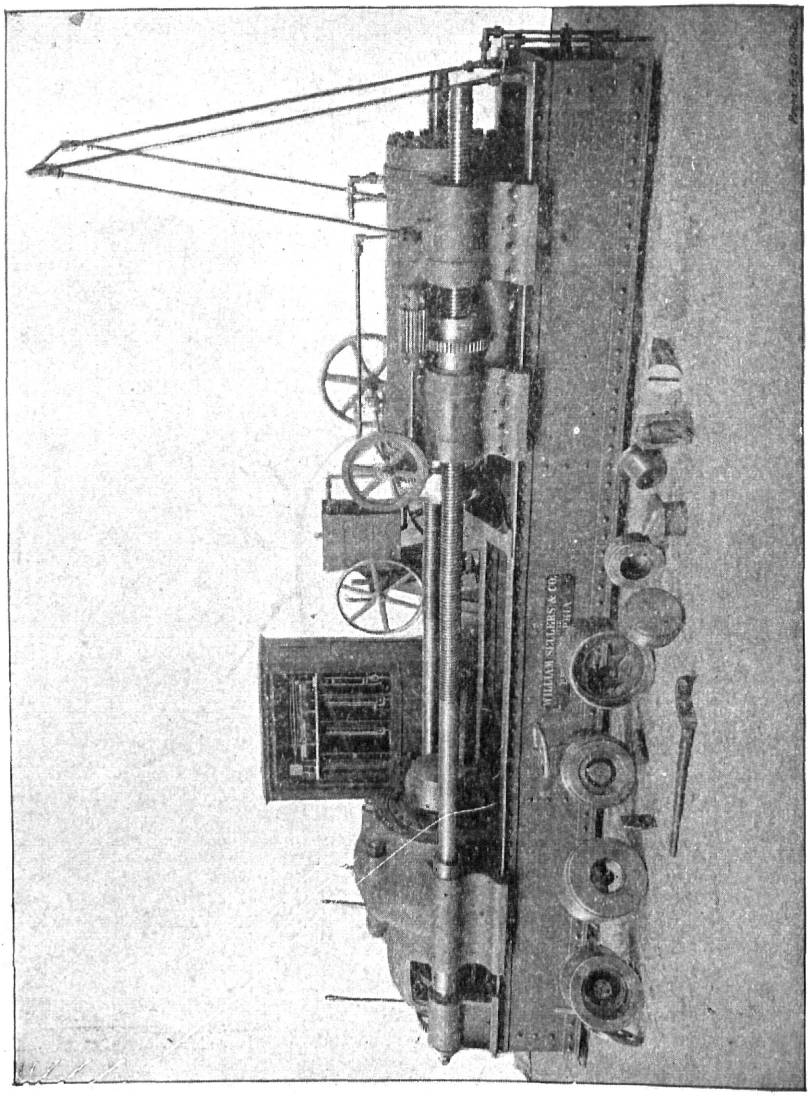

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Digest of Physical Tests.

CONTENTS.

Portrait of George Wallace Melville, ... FRONTISPIECE.
George Wallace Melville, ... *Frederick A. Riehlé*, . . 1
Longitudinal *vs.* Transverse Strength of Steel Plates, ... *Prof. C. H. Benjamin*, . 3
Testing, ... 13
Strength of Welds, ... 15
Physical Tests of Materials, ... *R. H. Thurston*, . . . 16
Alloys of Iron and Nickel, ... *Prof. M. Rudeloff*, . . 27
Comparative Analysis of the Resolutions, ... 32
The Refractive Index of Lubricating Oils, ... *G. W. Bissell*, ... 64
Investigations Regarding the Influence of Cold upon the Strength of Iron and Steel, ... *Prof. M. Rudeloff*, . . 65
Effect of an Addition of Gypsum to Portland Cement, ... 73
Strength of Cement Mortars after Hardening for some time in the open air, ... 74
Bicycle Frame Tests—Luminum *vs.* Steel Tubes, ... 75
NOTES AND COMMENTS, ... 76
Literature—Notes on Mechanical Laboratory Practice.
Appendix, ... 77

R. 10114

ALPHABETICAL INDEX TO ADVERTISERS.

Bliss, E. W. Co.,	x
Book Department,	viii
Cramp's Ship Yard,	xiv
Digest of Physical Tests,	iii, iv, v, Inside of Back Cover.
Donaldson, J. W. & Co.,	x
Latrobe Steel Co.,	ix
McCollin, Thos. H. & Co.,	ix
Paxson, J. W. & Co.,	x
Philadelphia Engineering Works, Limited,	ix
Riehlé Bros.,	ii, vi, vii, Outside Back Cover.
Riehlé-Alden Automatic Absorption Dynamometer,	xii
Sellers, Wm. & Co., Incorp.,	Inside Front Cover.
Stuebner, G. L.,	ix
The Sormovo Locomotive Manufacturing Co.,	xi
Union Central Life Insurance Co.,	xiii
Weidersheim, John A ,	ix

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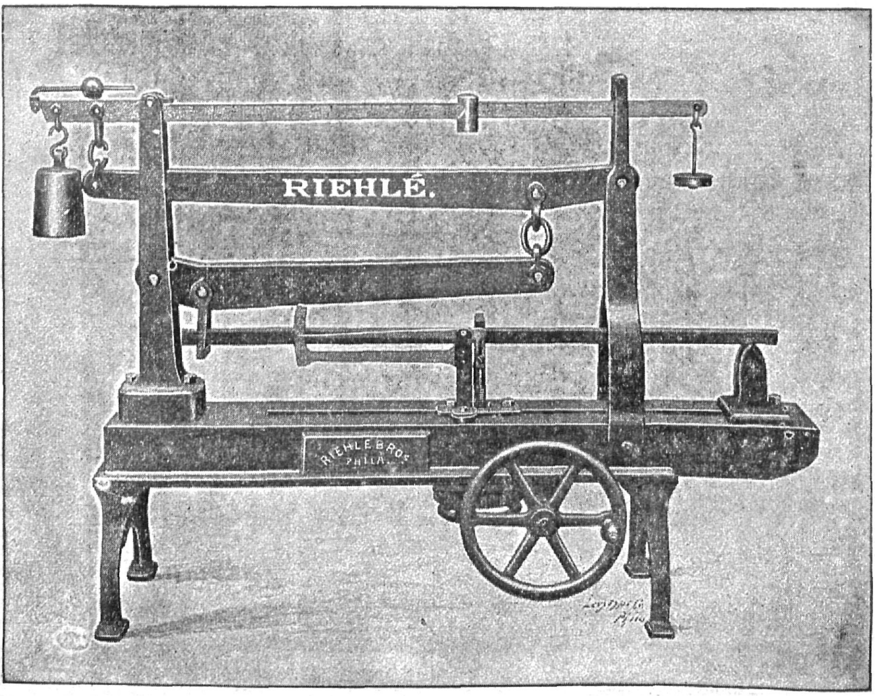

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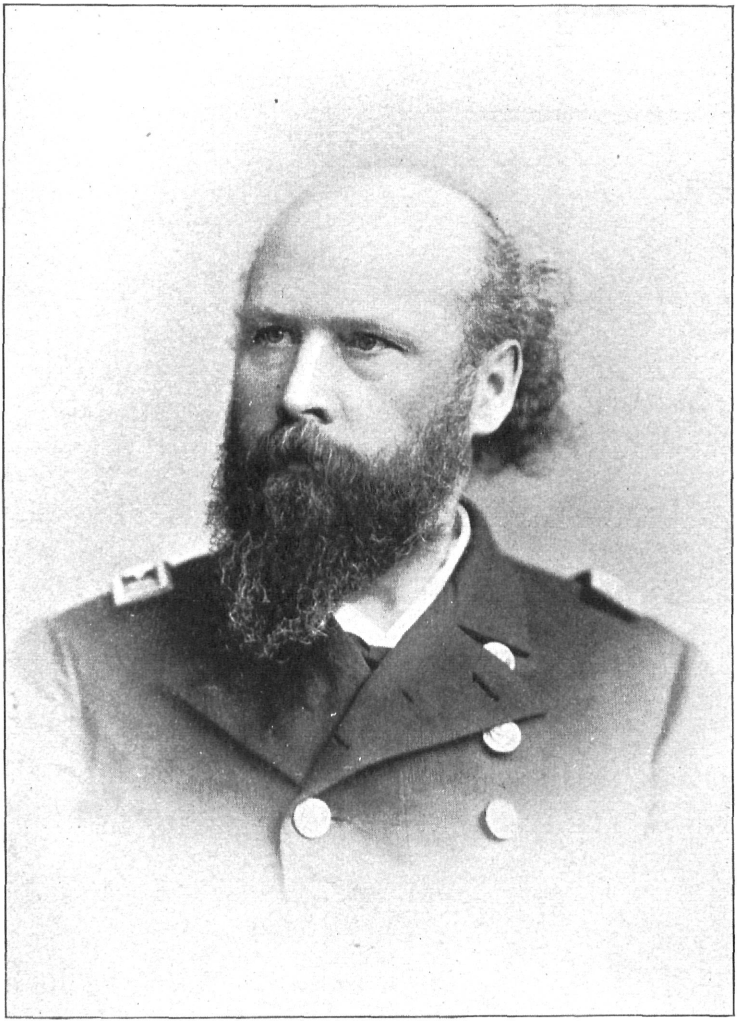


Geo W Melville
Engineer in Chief U.S.N.

Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. II. **JANUARY, 1897.** **No. 1.**

GEORGE WALLACE MELVILLE.

By Frederick A. Riehlé.

THE subject for our frontispiece of this, the January number of THE DIGEST OF PHYSICAL TESTS, is well known to most of our readers, and needs no introduction. George Wallace Melville, Engineer-in-Chief of the United States Navy and Chief of the Bureau of Steam Engineering, was born in the city of New York, January 10th, 1841. He traces his ancestry far back to noble Scottish lineage. He attended the public schools of New York City, particularly Grammar School No. 3, then the Christian Brothers' and Polytechnic School, of Brooklyn, N. Y. About 1860 he completed his term of apprenticeship in the mechanical trades with James Binns' East Brooklyn Machine works, Brooklyn, N. Y. In July, 1861, he received an appointment as Third Assistant Engineer in the Navy of the United States, and served throughout the war in Governmental service, and has continued in the same to the present date.

Mr. Melville has advanced step by step through almost every grade, and has now attained the highest position in the Navy Department. His last promotion secured him the high rank of Commodore.

We enumerate below some of the official positions Mr. Melville has held, showing this distinguished and eminent engineer's busy and eventful career. In 1870 Mr. Melville occupied an important Brazilian station; then a short cruise was made by him to the Arctic in the "Tigress;" this was in connection with Hall's Relief Expedition; then a trip to China and Japan and the East Indies until 1878. In April, 1879, he joined the "Jeannette" Arctic expedition, sailing for the Arctic region July, 1879. The success of this expedition was mainly due to the intelligent and painstaking equipment of the vessels, especially the judicious selection of all the various articles of clothing, diet, etc., etc., to which Mr. Melville gave his personal supervision in every detail.

The history of this expedition is well known by every reader who has been entertained and startled by the perilous adventures of the brave men who passed several years of their lives within the Arctic Circle. This first expedition occupied from 1879 until June 12th, 1882. The "Jeannette" was crushed in the ice, and the explorers were obliged to abandon it and escape on sledges, and finally returned to New York on September 13th, 1882. In 1883 he was a member of Greely Relief Expedition and rendered efficient service in fitting out and serving on the "Thetis" of the Relief squadron.

In 1886 we find this engineer on duty at Messrs. Cramp Ship Yard, Philadelphia. In 1887 he received the appointment of Chief of Bureau of Steam Engineering and Engineer-in-Chief of the Navy, which position he has held ever since. His present term of duty will expire January 16th, 1899. Under existing law the Commodore will retire from active service January 10th, 1903.

Scarcely any official in the U. S. Government service has been the recipient of as many titles and decorations as Commodore Melville. They are almost too numerous to mention; among the most prominent might be noticed the following:

Doctor of Engineering; E. D. Degree conferred by Stevens Institute, Hoboken, N. J.; Gold Medalist by Act of Congress of the United States, and promoted fifteen numbers for heroic and meritorious service in the Arctic; Honorary member of Society of Naval Architects of Great Britain; Honorary member Society Anthropology and Geography, Sweden; Member of National Geographical Society of the United States; also of the Geographical Club of Philadelphia; Military Order of Loyal Legion; Grand Army of the Republic; Naval Order of the United States; Society of Mechanical Engineers of the United States; Naval Architects and Marine Engineers of the United States.

It is not the intention of the writer, nor is it necessary to attempt to add any praise to or enlarge upon the merits of our distinguished countryman. Too often indeed it is the case, after their decease, to honor those whose incessant application in their calling has elevated them to the highest positions. Instances can be recalled of conspicuous examples of sad neglect, and unrequited reward, as the only returns of heroic service; nor is this peculiar only to the United States. It therefore affords us pleasure to note the many expressions of esteem and admiration already tendered the subject of this article, and we desire to emphasize this fact. We wish Commodore George Wallace Melville a continuation of that which he has so rightly earned by his labors—success.

LONGITUDINAL VS. TRANSVERSE STRENGTH OF STEEL PLATE.

By Prof. C. H. Benjamin, Case School of Applied Science, Cleveland, O.

IN building the ordinary forms of steel boilers it has been the custom formerly to run the plates around the shell instead of lengthwise, thus bringing the longitudinal strength of the plate in the direction of the greatest fibre stress. With the introduction of steel in place of iron as a material for boiler shells, this arrangement has been done away with to a large extent and the lower half of the shell has been made of one steel plate running lengthwise of the boiler, with no ring seams over the fire to cause trouble by scale and overheating.

This has been done on the assumption that steel plate, being homogeneous in texture and not fibrous, has the same strength in either direction. Although the truth of this assumption is pretty generally recognized by steel manufacturers, some makers and users of boilers have been rather skeptical on the subject, and the writer has not seen much definite information published in regard to it. The experiments to be described were made under the direction of the writer in the mechanical laboratory of the Case School of Applied Science by Mr. R. B. Kernohan as a part of his graduating thesis.

Four pieces of steel boiler plate, each 30x16x3/8 inches, were purchased from the manufacturers, two from the Otis Steel Company of Cleveland, and two from the Parke Bros. Company of Pittsburg, one piece being flange and one marine steel in each case.

The direction of rolling was ascertained and marked on each plate. As there is no desire to compare the products of the two firms mentioned, the names will be omitted in describing the tests. The plates were marked off, numbered, and finally sheared in the manner shown clearly by Fig. 1. The test-pieces were made from these strips by milling to the standard shape of tension specimens for flat plate, with a distance of eight inches between marks.

Mr. Kernohan made careful analysis of samples from each plate, determining the carbon, sulphur, phosphorus, and manganese.

The specimens were all tested for tensile strength and ductility in a Riehlé 60,000 lb. testing machine owned by the school. Autographic diagrams of the elongation were made by the use of a new recording extensometer devised by the writer and shown in Fig. 2; from these the elastic limit and modulus of elasticity were determined.

Tables 1 to 4 show the results calculated from the experiments, the numbers referring to the marks on the specimens, as shown in Fig. 1. These tables explain themselves, and it is only necessary to say that the elastic limit in each case was determined by inspection of the characteristic curve drawn by the extensometer, and that as this line is a curve of gradually increasing curvature from the origin to the elastic limit (see Fig. 3) there is no constant value of the modulus E. The first value in each case is calculated from the elongation at the elastic limit, and the second value from the elongation at one-half the elastic limit. The latter value corresponds quite closely to what would be obtained by using the tangent to the curve at the origin. A careful study of the tables will convince any one that there is practically no difference in their main characteristics between the longitudinal and the transverse strips. The differences between consecutive pieces from the same set are often greater than the differences between averages of the two sets.

The specimens Nos. 43 to 48 were of uneven thickness, and consequently broke near one end. This made any calculation of the percentage of elongation impossible and rendered the values for contraction and for unit stress somewhat uncertain. With these exceptions the experiments can be relied upon.

As the extensometer used in these experiments is of a new pattern designed by the writer, and this is the first extended use that has been made of it, a brief description of the instrument will be given.

TABLE I.—NO. I FLANGE STEEL.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Longitudinal.	1	43.1	26.3	34,980	58,290	18,170,000	38,160,000
	2	46.6	28.1	34,760	57,500	19,310,000	40,390,000
	3	47.4	24.4	34,980	58,370	21,860,000	. . . . .
	4	45.9	26.5	34,980	58,060	18,900,000	42,910,000
	5	47.2	25.6	35,630	58,270	19,200,000	38,160,000
	6	40.1	25.0	35,050	57,850	18,940,000	43,000,000
	Av.	45.1	26.0	35,063	58,057	19,393,000	40,520 000
Transverse.	7	44.6	24.4	34,650	58,270	18,480,000	44,150,000
	8	44.4	24.4	33,550	58,730	26,840,000	41,560,000
	9	46.1	23.8	33,550	58,490	26,840,000	39,250,000
	10	44.5	22.5	34,520	59,470	15.010,000	64,800,000
	11	45.2	23.8	35,680	58,170	23,780,000	45.440,000
	12	46.4	25.0	34,650	58,390	27.730,000	50,460,000
	Av.	45.2	24.0	34,433	58,587	23,113,000	45,943,000

Chemical Analysis, C = 0.18%, S = 0.04%,
P = 0.032%, Mn = 0.45%.

TABLE II.—NO. I MARINE STEEL.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Longitudinal.	13	62.0	31.9	25,810	47,690	17,200,000	42,730,000
	14	64.3	35.0	25,820	47,230	16,660,000	52,425,000
	15	62.1	32.5	26,330	47,690	30,080,000	55,440,000
	16	62.8	33.8	25.920	47,130	19,200,000	39,320,000
	17	66.5	33.1	24,880	46,890	21,635,000	50,040,000
	18	64.8	32.5	26,310	47,020	20,240,000	45,770,000
	Av.	63.7	33.1	25,845	47,275	20,836,000	47,621,000
Transverse.	19	58.5	33.7	25,850	47,600	23,500,000	42,060,000
	20	62.7	33.8	25,920	47,000	23,560,000	39,500,000
	21	67.0	33.1	25,570	46,970	26,225,000	45,260,000
	22	60.0	32.5	26,590	46,820	18,330,000	45,450,000
	23	60.1	33.1	26,910	47,320	15,380,000	46,410.000
	24	59.9	33.1	26,730	47,120	22,270,000	50,800,000
	Av.	61.4	33.2	26,260	47,140	21,544,000	44,827,000

Chemical Analysis, C = 0.13%, S = 0.026%,
P = 0.004%, Mn = 0.45%.

As shown in Fig. 2, the extensometer is of the lever type and records the extension directly on a revolving drum multiplying the elongation in the ratio of 50 to 1. The object in designing this instrument was to make an extensometer which should be attached directly to the specimen and should be self-contained, not touching the testing machine itself and consequently not being affected by springing of the machine or by slipping of the jaws. It was desired that the instrument should contain the least possible number of moving parts and should be free from the errors due to the use of cords or belts.

Referring to Fig. 2, F and G are the upper and lower grips respectively, which are attached to the specimen, T, by pointed steel thumb-screws and connected together by a piece of light brass tubing. The lower grip, G, is pivoted to a collar which can be adjusted vertically on the brass tube by means of milled check-nuts. To G is attached the light steel lever L, carrying at its outer end the pencil or pen, P.

The lever is so proportioned that RP is 30 inches and the distance from the fulcrum, R, to the pointed screw is 0.6 inches, giving a multiplication of 50 to 1. The screw S enables the operator to adjust the pressure of the pencil on the paper, while the milled nuts and sliding collar on the lower grip provide for a vertical adjustment of the pencil.

By means of a bronze elbow the horizontal brass tube H, carrying the drum D, is attached to the extensometer in such a manner that the drum may be swung horizontally into the most convenient position for recording. The drum is rotated by a small worm, W, which in turn is connected by means of a very light double Hooke's joint to a shaft on the testing machine. This latter shaft is geared directly to the hand wheel which moves the poise on the beam of the machine. The drum is thus rotated an amount proportional to the load on the specimen, while the pencil moves up on the attached paper an amount proportional to the elongation of the specimen.

It will be seen that this instrument has no connection with the testing machine itself, except through the medium of the jointed shaft which drives the drum. This shaft is made of light tubing and is telescopic, so that there can be no pull or push exerted on the drum, and as the latter turns very easily there can be no appreciable deflection of the apparatus from this cause.

This particular instrument was designed for attachment to a

Riehlé machine, but it can be easily applied to any vertical testing machine. It may be thought that the instrument is rather heavy to suspend directly to the specimen, but no difficulty has been found in this respect. The present instrument, an experimental one, weighs but 5 lbs., and exerts a horizontal pull of only 8 lbs. on the screws of the upper grip.

If it were thought desirable, by employing aluminum and steel the weight could probably be reduced to three pounds, but the writer has found a certain mass to be of advantage to ensure freedom from vibration.

In Figs. 3 and 4 are shown sample autographs taken by this extensometer, one autograph from each set, as figured in Tables 1 to 4.

TABLE III.—NO. 2 FLANGE STEEL.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Transverse.	25	52.7	28.1	33,780	55,340	14,080,000	35,560,000
	26	50.4	26.9	33,340	55,340	14,490,000	44,440,000
	27	51.3	28.1	32,480	55,960	20,305,000	36,460,000
	28	50.7	27.5	31,340	55,110	17,910,000	40,140,000
	29	53.6	27.5	31,640	55,275	25,320,000	35,530,000
	30	50.0	28.1	30,360	55,460	18,400,000	42,020,000
	Av.	51.5	27.7	32,157	55,414	18,417,500	39,025,000
Longitudinal.	31	48.3	25.0	30 550	54,675	24,460,000	32,580,000
	32	39.1	12.5	32,960	57,250	11,990,000	42,040,000
	33	55.9	28.8	32,590	56,075	25,080,000	35,975,000
	34	54.5	25.6	32,920	56,200	26,340,000	54,200,000
	35	49.5	25.6	33,130	55,700	14,400,000	38,960,000
	36	52.8	25.6	33,610	55,600	24,560,000	40,720,000
	Av.	50.0	23.4	32,627	55,917	21,138,000	40,746,000

Chemical Analysis, $C = 0.19\%$, $S = 0.052\%$,
$P = 0.04\%$, $Mn = 0.45\%$.

TABLE IV.—NO. 2 MARINE STEEL.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Transverse.	37	51.3	25.0	34,350	58,290	19,630,000	39,960,000
	38	53.6	24.4	34,290	57,900	28,580,000	59,740,000
	39	53.1	27.5	32,790	56,150	22,610,000	36,430,000
	40	57.0	25.0	31,170	55,360	15,990,000	50,640,000
	41	52.3	26.9	32,760	55,590	24,270,000	47,230,000
	42	53.0	28.8	31,810	55,710	21,210,000	35,020,000
	Av.	53.4	26.3	32,862	56,500	22,048,000	44,837,000
Longitudinal.	43	63.0	. . . .	33,080	51,910	25,450,000	40,140,000
	44	65.6	. . . .	34,630	51,150	26,640,000	52,430,000
	45	61.0	. . . .	34,800	51,290	25,780,000	41,250,000
	46	63.4	. . . .	32,830	51,710	26,270,000	40,680,000
	47	63.5	. . . .	33,140	51,150	25,500,000	38,900,000
	48	60.6	. . . .	33,180	53,290	27,590,000	37,560,000
	Av.	63.0	. . . .	33,610	51,750	26,205,000	41,827,000

Chemical Analysis, C = 0.13%, S = 0.031%,
P = 0.028%, Mn = 0.46%.

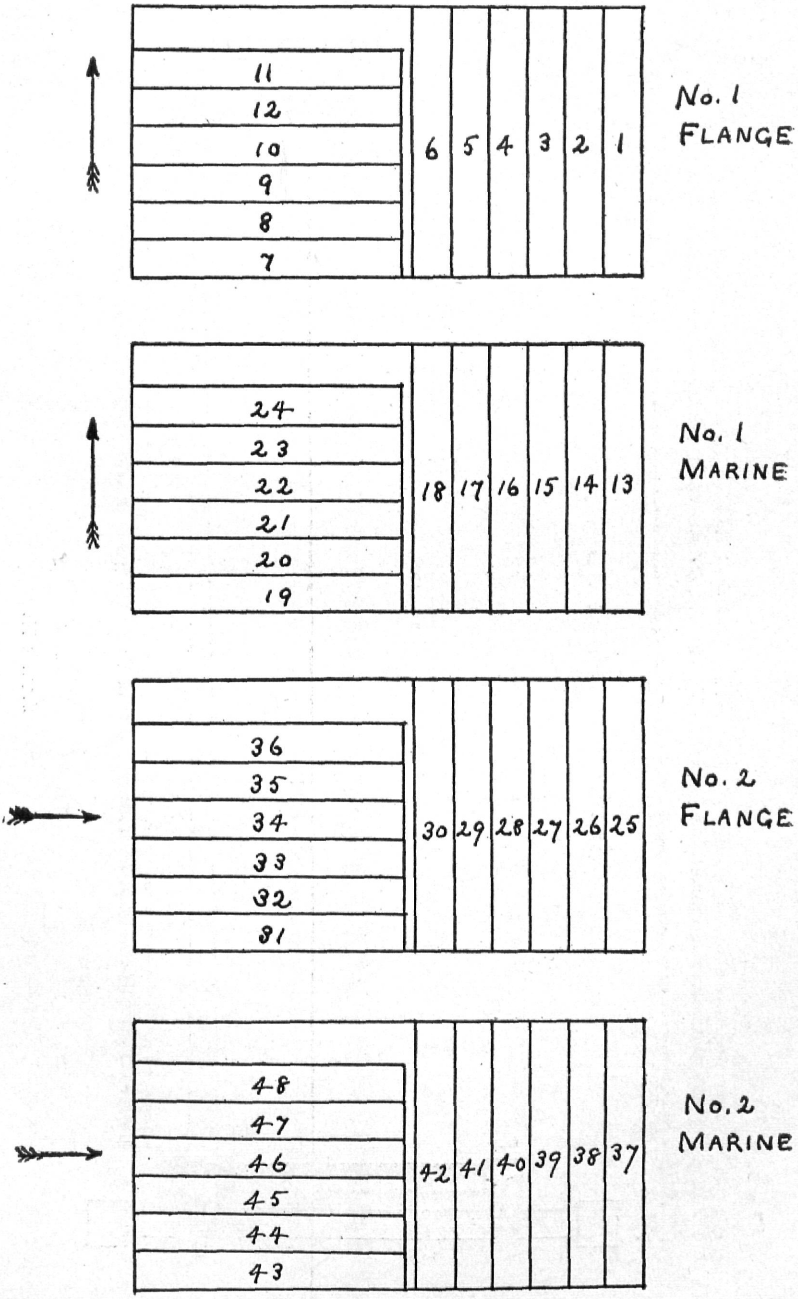
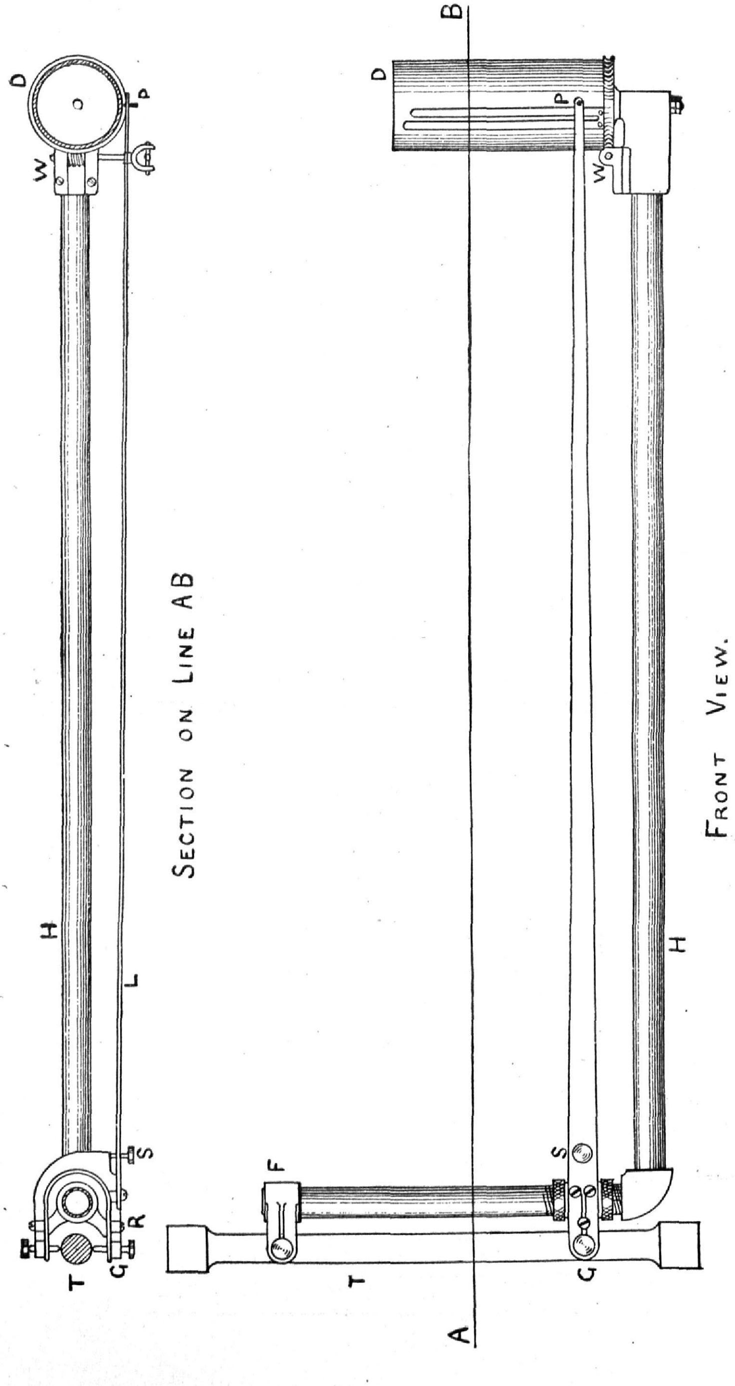

6 5 4 3 2 1
No. 1
FLANGE
18 17 16 15 14 13
No. 1
MARINE
30 29 28 27 26 25
No. 2
FLANGE
42 41 40 39 38 37
No. 2
MARINE

FIGURE I.



SECTION ON LINE AB

FRONT VIEW.

FIGURE II.

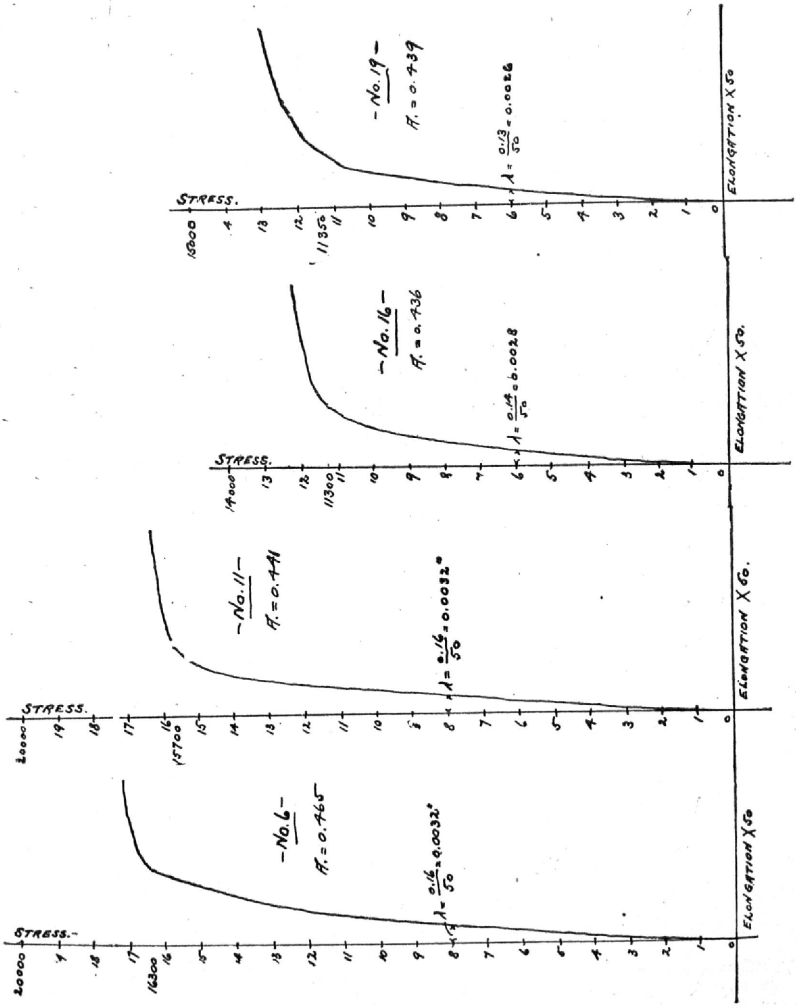

STRESS.
20000
16300
ELONGATION X 50
–No. 6–
A. = 0.465
λ = 0.16/50 = 0.0032"
STRESS.
20000
15700
ELONGATION X 50.
–No. 11–
A. = 0.441
λ = 0.16/50 = 0.0032"
STRESS.
14000
11300
ELONGATION X 50.
–No. 16–
A. = 0.436
λ = 0.14/50 = 0.0028
STRESS.
15000
11350
ELONGATION X 50
–No. 19–
A. = 0.439
λ = 0.13/50 = 0.0026

FIGURE III.

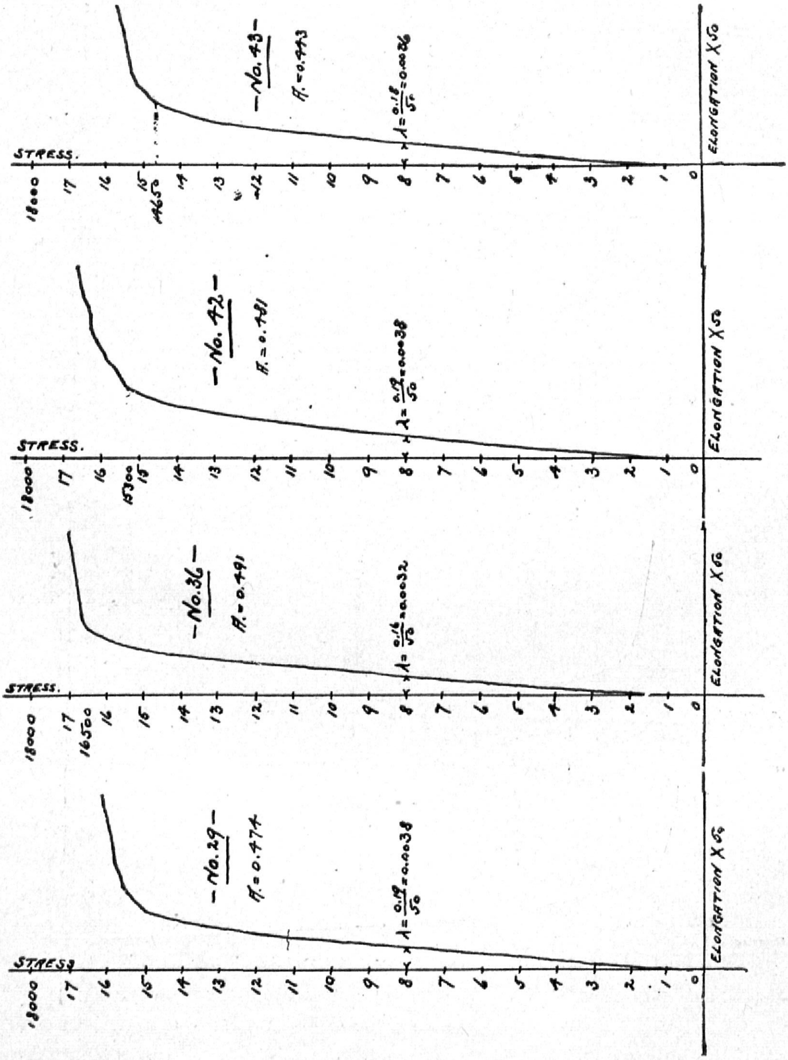

STRESS.
18000
17
16
15
14650
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
ELONGATION X 50
-No. 43-
A. = 0.443
$\lambda = \frac{0.18}{50} = 0.0036$
STRESS.
15300
ELONGATION X 50
-No. 42-
A. = 0.481
$\lambda = \frac{0.19}{50} = 0.0038$
STRESS.
16500
ELONGATION X 50
-No. 36-
A. = 0.491
$\lambda = \frac{0.16}{50} = 0.0032$
STRESS
ELONGATION X 50
-No. 29-
A. = 0.474
$\lambda = \frac{0.19}{50} = 0.0038$

FIGURE IV.

TESTING.

IT is questionable if any department of mechanical science has made such rapid strides for the determination of reliable data as testing. If we look at the matter in a common-sense way, nothing else but gradual improvement can be expected. Among mechanicians who are constantly engaged in new developments, an every-day-expression is "wonder how it will stand?" The answer comes, "try it, test it." To accomplish all the requirements of testing means an immense amount of study; a thorough knowledge of machine design of the most accurate form, and an up-to-date experience in the material used for testing. In Britain and Europe testing has long been an established necessity for almost every commercial article upon which any reliance is demanded. We here are pushing forward, in every branch of this most interesting science, to obtain best results in manufacture, to possess reliable data, and to check the manufacturer who would—were it not for testing—send out an inferior and faulty article.

Our esteemed contemporary, *The American Machinist*, in its issue of November 26th, seems rather inclined to throw a shadow over this all-important subject, suggesting that "horse-sense and a knowledge of dark ways, etc., are needed to detect the efforts of interested parties to deceive the expert in charge."

Expert is a term used to define one thoroughly versed in a subject upon which he is engaged. Unfortunately, in many instances, the man in charge is not equal to the term, hence it proves inexperience in this direction is alone responsible for bad and "watered" tests. But this fact does not show that the science is at fault.

Further on *The Machinist* proclaims that the "real brain-racking problems are solved over the drawing-board and in the shop."

I have often heard it said, and seen verified in practice, that "money is made and lost in the drawing-room." It would appear to any engineer of common sense that the less his assistants knew about the physical properties of the material used in construction, the greater would be the errors and consequently his losses. To us it seems absolutely impossible for any student or engineer in practice to devote himself to construction without a very large and correct knowledge of the physical properties of material upon which he is engaged—whether he got this from text-books or otherwise, it is purely the outcome of the result of testing. It is possible that there are investigations made in schools totally unnecessary for practice and perhaps have absorbed much time and expense in their preparation, yet it is and must be interesting to the student, for he gleans much from the contact with the operation, in being able to investigate the delicate machinery and its mode of construction. In these elaborations it is not testing, nor is it the student, to blame, but the professor who, perhaps due to his advanced ideas, has a failing toward measuring the infinite. *The Machinist* would have us believe that the only subject studied in our engineering schools is machine design. Civil, electrical, and mining engineers all are intensely interested in the development of the physical properties of materials through the medium of testing.

Our contemporary says: "Machine building is primarily a matter of business and not of science, and this worship of tests and efficiency tends directly to obscure this fact and to lead to the reverse conclusion."

Experience alone is the "matter of business," which is only the outcome of endless contact with the possibles and impossibles, investigating previous experience, experimenting on that which has been done; in short, it comes down to a most potent yet simple fact: trial or test; it is undeniably the practice, and is the only means of proving or disproving theory. The more we test and measure the efficiency of a machine the better able are we to determine the quality of material; the best mode of improving its defects, whether this or that oil is best suited for its lubrication, etc. A testing laboratory is of the utmost importance, because it often sayes much labor in predetermining a quantity otherwise unsolvable, thus giving the constructor confidence in his work, relieving him of the uncertainty and worry of waiting the result of failure or success in any detail of his work after its construction. Again our contemporary complains of the elaborate machinery in our schools. If a little time was given in figuring out the number of students attending the mechanical engineering courses, and allow that each one should himself participate in the preparation and carrying out of a test, it will be found that nine cases out of ten the experimental machinery is miserably inadequate, making it impossible for the individual student to test alone, or even in company with another. Generally our colleges that have good incomes, and whose patrons believe in bringing students in close touch with the times, provide experimental machinery in proportion to the demands made upon it. Other poorer institutions struggle along without such necessities, but always in a complaining tone, deploring their condition. But it is not the schools that have all the testing appliances. Nearly every engineering concern of repute has a testing room of some sort, many extremely elaborate. May we ask, is it because they have money to throw away? No; they appreciate the fact of being able to determine themselves the means whereby they can improve their output, or their machines, as the case may be, and fill the conditions of a binding contract. Thus we see the schools are endeavoring to follow only in the wake of actual practice, guided by their able instructors, the majority of whom are men in close harmony with things that are and can be, who feel the importance of machinery for experiment as object lessons, to hasten the students' education in so wide a field. Many of our old instructors envy the path of students nowadays, because of the easy access to the means of solving problems they had to struggle years to determine. As time advances greater knowledge is developed, greater demands are made upon man, and he alone can succeed who is cognizant of the present condition of the sciences. He alone can stand the test.

EDITOR.

STRENGTH OF WELDS.—Some experiments made at the engineering laboratory of the University of Michigan to determine the strength of welded joints are especially interesting. Of a number of the specimens tested not one broke in the weld; as some of these were slightly larger at the weld, a new set of specimens was prepared and a cut taken from each in the lathe to reduce the piece to a uniform diameter throughout its length between the jaws of the testing machine. Common round iron was used. Three bars were taken at random; 1¼ inches, 1 inch, and ¾ inch in diameter. From each bar four specimens were prepared, one solid, one lap-welded, one butt-welded, and one split-welded. The results show that only two specimens, both lap-welded, broke at or near the weld; the fracture in one case was slightly crystalline and in the other fibrous. The strength in no case departed widely from the strength of the solid parts. It would seem from these tests that with skillfully made welds we may expect to realize nearly the full strength of the original bar.

PHYSICAL TESTS OF MATERIALS.

By R. H. Thurston, Director, Sibley College, Cornell University, Ithaca, N. Y.

IT gives me great pleasure, in compliance with the request of the editor of THE DIGEST OF PHYSICAL TESTS, to submit a few suggestions relative to methods and purposes of some such work that may perhaps prove helpful to those seeking to find a special field of research in this department. The value of the matter already accumulated and so well presented in this journal is, perhaps, the best possible evidence that the skilled investigator in engineering can find no field in which his explorations are likely to be more fruitful of valuable and professionally helpful result. A few historical reminiscences may suitably introduce the subject-matter and preface our conclusions.

In the course of the year 1873 plans for the organization of a "Mechanical Laboratory," given shape in 1871 and earlier by the writer, began to take material form, and that year was marked by the entrance of their author upon a series of investigations relative to the various effects of method and time of stress and of strain upon the materials of construction, using for much of the work a form of "autographic recording testing machine," which was, so far as known, the first of that class. The first test-piece placed in the machine gave an "autographic" diagram on which was recorded a discovery which attracted very general attention, and proved the introductory to a very extended series of researches in his own laboratory and also abroad. It was the recorded fact of "the exaltation of the normal elastic limit-series by time and strain." This discovery was reported to the American Society of Civil Engineers in the autumn of that year.*

The effect of the "Flow of Metals," and of the force of polarity described by Prof. Henry, in modifying their resistance to external stress and their strain, was stated by the writer as follows: †

"The same molecular movement, or flow, which rearranges the internal force and relieves internal strain may be a phase of that viscosity which Vicat supposed might in time permit rupture of metal subjected to stress nearly approaching its original ultimate resistance, the one action being a more immediate result than the other, and the latter producing its effect, even when cohesive force may have been actually intensified.

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* *Trans. A. S. C. E.*, Vol. III, p. 13.

† *Ibid.;* also *vide Trans. A. S. C. E.*, March 1st, 1876.

"It was noted, however, that in the cases in which wrought iron and steel had been subjected to stress exceeding the elastic limit the metal had exhibited no tendency to flow, and that in nearly every case observed an actual 'elevation of the elastic limit by strain' had taken place. No experiment had then been made by the writer in which the same sample had exhibited both the elevation of the elastic limit by strain and the phenomenon of flow.

"Since that time, when experimenting upon copper, strain-diagrams produced automatically have been observed to exhibit this double effect. The elevation of the elastic limit has occurred in the earlier part of the test, and, at a later period, the strain-diagram exhibits flow, the metal yielding under a gradually decreasing stress. The progressive distortion which had never been observed by the writer in iron or steel, has since been frequently noted in other materials."

* * * * * * *

The paper referred to thus enunciated a principle which was deduced from experiments on wrought iron which is, if possible, of more vital importance to the engineer than the facts just given, viz.: That the time during which applied stress acts, is an important element in determining its effect, not only as an element which modifies the effect of the *vis viva* of the attacking mass and the action of the inertia of the piece attacked, but, also, as modifying seriously the condition of production and relief of internal strain by even simple stresses.*

It was also shown, by autographic strain-diagrams, that some materials yield the more readily the more rapidly the distortion and rupture are produced, their resistance varying in some inverse ratio, with the rapidity of change of form. It was further indicated that this action might be closely related to the opposite phenomenon of the elevation of the elastic limit by strain. An explanation was offered in the theory that, with rapid distortion insufficient time is allowed for the relief of internal strain in materials capable of exhibiting that condition. It was further remarked that "the most ductile substances may exhibit similar behavior, when fractured by shock or by any sudden applied force, to substances which are comparatively brittle," and illustrations were given of such behavior, and the precautions to be taken by the engineer, in view of this important modification of the resistance of materials by velocity of rupture, were stated.

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* Vol. III, page 30. LXI. Vol. II, page 239. CXV. Vol. IV, page 334.

"Should it be true, as suggested by the writer, that the cause of the decreased resistance, sometimes observed with increased velocity of distortion, is closely related to the cause of the elevation of the elastic limit by strain,* it would seem a simple corollary, that *materials so inelastic and so viscous as to be incapable of becoming internally strained during distortion should offer greater resistance to rapid than to slowly produced distortion,* in consequence of their inability to 'flow' so rapidly as to reduce resistance by such fluxion at the higher speed, or by correspondingly reducing the fractured section. This principle has been shown, by a large number of experiments, to be frequently, if not invariably, the fact. Copper, tin, and other inelastic and ductile metals and alloys are found to exhibit this behavior, and are, therefore, quite opposite in this respect to ordinary wrought iron and worked steel."

The writer had noted the fact that very soft wrought iron does not always exhibit an observable elevation of the elastic limit by strain, and Com. L. A. Beardslee, U. S. N., had observed that the softest and most ductile specimen of iron then tested by him at the Washington Navy Yard exhibited a perceptible increase of resistance with a considerable increase of rapidity of extension. This metal was peculiar in its softness and extreme extensibility. All the irons of commerce appear to belong to the other class, as then shown.

Autographic strain-diagrams, given by this class of metals, exhibited smooth, straight, and horizontal lines for long distances on the paper where the distortion is produced by a uniform motion. Increasing the rapidity of distortion caused an immediate and sustained elevation of the pencil, and a decrease of velocity causes the line to droop to a lower level. In some experiments a torsion of one revolution in a half-hour, the test-piece being ⅝-inch diameter and one inch long, just kept the pencil on a horizontal line.

Two test-pieces from the same bar were broken, the one rapidly, the other slowly. The former gave a strain-diagram of which

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* *Transactions,* Vol. III, page 363.

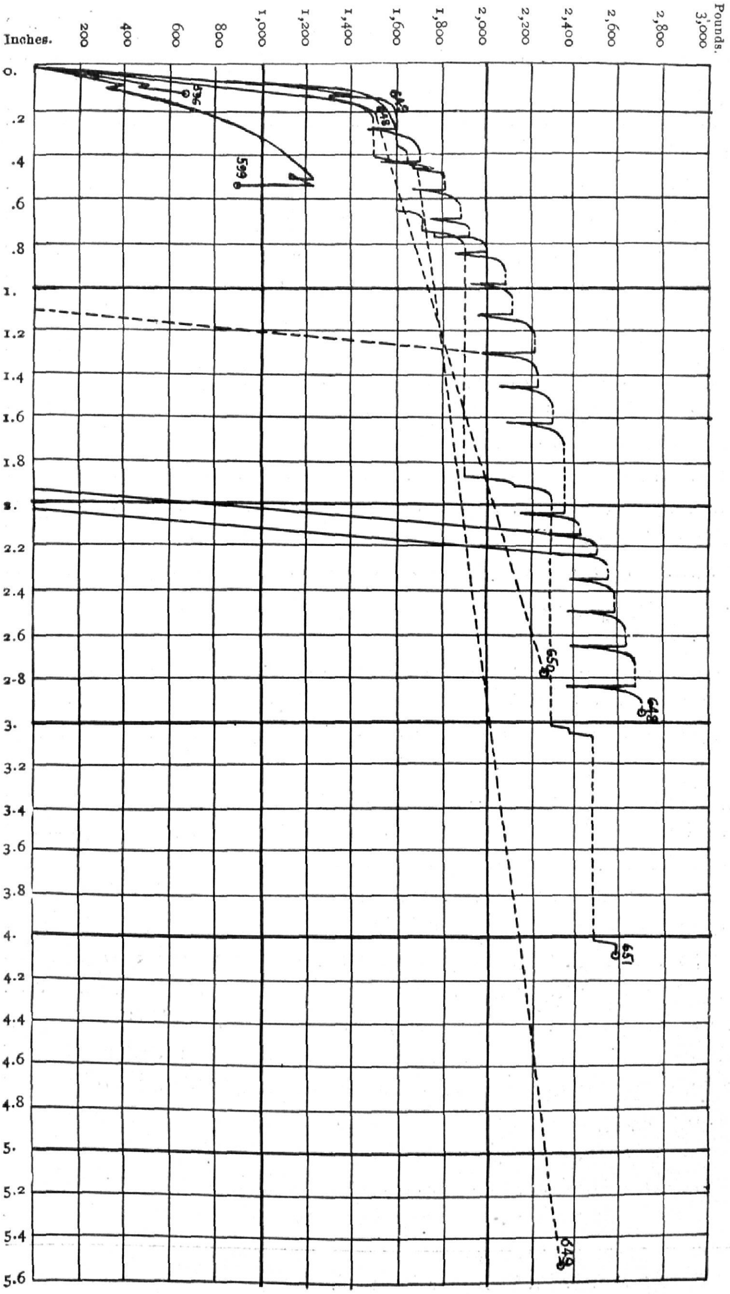

FIG. 1.—STRAIN-DIAGRAMS OF FOUR BARS OF WROUGHT IRON, AND TWO OF COPPER-ZINC ALLOYS TESTED BY TRANSVERSE STRAINS. ROBERT H. THURSTON.

the maximum ordinate was about 50-foot pounds higher than the maximum of the latter, the difference being nearly 50 per cent. of the higher.

"It is evident that, whatever the character of the material and whatever the velocity of rupture, the effect of the *inertia* of the mass, and of particles not immediately affected by a shock, remains, and that its effect is *always* to reduce the resilience of the metal and its resistance to shock; and this reduction may, in many cases, more than compensate the increase of resistance here noted. Its tendency is always to produce a sharp fracture which, with such sudden blows as are given by cannon shot, for example, may resemble the break characteristic of brittle and non-ductile substances."

The writer proposed, therefore, to divide the metals used in construction into two classes:

1st. Metals subject to internal strain by artificial manipulation and which may exhibit an elevation of the elastic limit by strains and decreased power of resisting stress under increasing rapidity of distortion. The ordinary irons of commerce are typical of this class.

2d. Metals of an inelastic viscous character, not subject to internal strain, and not usually exhibiting an elevation of the elastic limit by strain, and which offer increased resistance when the rapidity of distortion is increased. Tin is a typical example of this class.

It is obvious that the value of the former class for the construction of the engineer is vastly greater than the latter, and especially for permanent loads and low factors of safety.

A study was later made of "the rate of set of metals subjected to strain for considerable periods of time," and this was the subject of a report to the A. S. C. E., in which were discussed the two distinct phenomena: the "decrease of resistance at a fixed distortion" and "the observed increase of deflection under static load." *

It was found that, with a fixed and invariable deflection, for example, of a bar of any one of the considerable variety of metals tested, including iron and the brasses and bronzes, the effort of the flexed bar to regain its initial form became less and less as time progressed, often approximating zero, and, at last, in the case of the brittle metals, fracture might even occur at loads, as in one case, at least, 25 per cent. lower than those the same bars had earlier sustained, and at still unchanged flexures.* The deductions were:

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* *Trans. A. S. C. E.*, December 6th, 1876.

"That in metals of all classes, under light loads, this decrease of effort and rate of set become less and less noticeable until, after some time, no further change can be observed, and the set is permanent."

"That in metals of the 'tin-class,' or those which had been found to exhibit a depression of the elastic limit with strain, a heavy load—*i. e.*, a load considerably exceeding the proof-strain, the loss of effort continued until, before the set had become complete, the test-piece yielded entirely."

"And that in the metals of the 'iron-class,' or those exhibiting an elevation of elastic limits by strain, the set became a maximum and permanent and the test-pieces remained unbroken, no matter how near the maximum load the strain may have been."

On the other hand, loading the bar with a given weight and allowing it free suspension, so that the deflection might take care of itself, it was found that the irons and steels, and usually and rarely an alloy, would deflect continually, more and more, to a limit; the deflection then ceasing, the bar would remain, indefinitely, unchanged. On the other hand, nearly all metals and alloys would exhibit a continuous and unintermitted depression, if the freely suspended loads approached their ultimate resistances, and even, in some cases, if it were above one-half the maximum momentary load which the metal was capable of carrying, and fracture would in time result; the time being the greater as the load was the smaller, proportionally. For most metals and alloys, and even for the woods, it was thus finally concluded, "an apparent factor of safety of two is actually but a factor of one." The real factor of safety, for permanent loading, is in such cases but about one half that which appears from a simple ordinary testing machine determination. For iron and steel, this is less true, if not entirely the reverse.

Based upon this fact of the "exaltation of the normal elastic limit by strain," the writer proposed "a new method of detecting overstrain in iron and other metals, and its application in the investigation of accidents to bridges and other constructions." † It was shown that the phenomenon above described, as then discovered and announced by the writer, produced a permanent record in the material itself, of the maximum stress to which it had been subjected; the elastic limit of a bar of iron or of steel which had been thus strained being the approximate measure of the stress thus applied. In fact, the elastic limit may arise somewhat after the stress has been removed.

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* *Ibid.*, Section 1. Such fracture did not occur with iron.

† *Trans. A. S. C. E.*, March 20th, 1878.

For good bridge irons, the amount of the excess of the exalted limit, as shown by subsequent test, above the stress at which the load had been previously removed was expressed approximately by the formula:

$$E^1 = 5 \text{ Log. } T + 1.50 \text{ per cent.};$$

in which the time, T, is given in hours of rest after removal of the tensile stress which produced the noted stretch.

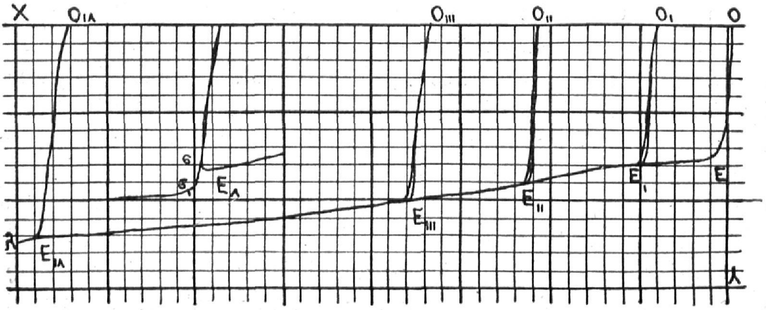

FIG. 2.—EXALTATION OF ELASTIC LIMITS.

"Thus, in the figure, which is a *fac simile* of a part of a strain-diagram produced by such an iron, during a test in which the intermission of stress was of too brief duration to cause an observable exaltation of the normal elastic limit in a diagram drawn on so small a scale, the point E is the primitive elastic limit of the material, and E^{I} E^{II} E E^{IV}, are the normal elastic limits corresponding to sets under loads which have strained it beyond that primitive elastic limit. In the example here illustrated the primitive limit is found at about 20,000 pounds per square inch, or 1,400 kilograms per square centimeter, and the other points are those corresponding to loads of, respectively, 21,000, 22,500, 25,000, and 30,000 pounds on the inch, or to 1,470, 1,575, 1,750, and 2,100 kilograms on the square centimeter. The corresponding extensions, as shown on the diagram, are 1.25, 2.53, 4.50, and 6.78 per cent.

Had the stress been intermitted at either of these points any considerable period of time, there would have been observed a rise in the diagram as above stated like that shown in Fig. 1, at E^{v} the normal elastic limit *e*, being, on subsequent test, found altered and a new limit, *e′*, observed. The extent of this elevation of the limit would be the greater as the time of rest was greater, as was then shown.

Thus it was proved that a metal, once overstrained, carries, permanently, unmistakable evidence of the fact,* and can be made to reveal the amount of such overstrain at any later time with a fair degree of accuracy. This evidence cannot be entirely destroyed, even by a moderate degree of annealing. Often only annealing from a high heat, or reheating and reworking, can remove it absolutely. Thus, too, a structure broken down by causes producing overstrain in its tension members, or in its transversely loaded beams (and, probably, in compression members, although the writer is not yet fully assured of the latter), retains in every piece a register of the maximum load to which that piece has ever been subjected; and the strain-sheet of the structure, as strained at the instant of breaking down, can be thus laid down with a fair degree of certainty.

Here, then, when the work thus performed shall have been properly complemented with experimental determinations of the behavior of all the materials of general use in construction, is to be found a means of tracing the overstrains which have resulted in the destruction or the injury of any iron or steel structure, and of ascertaining the cause and the method of its failure, in cases frequently happening in which they are indeterminable by any of the usual methods of investigation.

The fact of the normal variation of the elastic limit, as change of form progresses under gradually increased load, was fully established by the experiments of Hodgkinson, Clark, Mallett, and other English investigators; by Tresca, particularly, in France; by Werder and Bauschinger in Germany, and by Beardslee, the writer, and others in the United States.

The exaltation of the series of normal limits so produced, still further, as shown by the writer and as seen in Fig. 1, by the intermission of strain, as at E^{v}, is now a matter of no uncertainty as to its character, although still more study is needed to determine the modifying effects of time of intermission of stress with the two great classes and when not of the same composition. The method then outlined of determining the extent of previous overstrain may, therefore, be expected to have many useful applications.*

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* The writer has found by subsequent tests that every strain produces the same effect upon the elastic limit for all directions of stress.

It was shown in this paper that it is, in some cases, at least, perfectly possible to trace the varying stresses which have occurred in the members of a bridge, broken down by any accident, in such manner as to discover the point at which the maximum load was applied in its fracture, and thus to, in some cases, ascertain the probable cause and method of breakdown. A typical example, closely corresponding to an actual case investigated by the writer, was illustrated.

It was found, as then shown, that the load on the structure at the time of the accident was but sufficient to make the maximum stress on these rods—if properly distributed—20,000 pounds per square inch at the threaded part of the piece; which piece, it had been seen, had been broken by a strain nearly double that figure. The fact was at once inferable that the load came upon these members with such suddenness as to have fully the effect of a live load (as taken in the text-books) and giving a maximum stress equal to twice that produced by the same load gradually applied—*i. e.*, the case in which the load falls through a height equal to the extension of the piece strained by it, the resistance being assumed to increase directly as the extension up to the point of rupture—an assumption which is approximately correct for brittle materials like hard cast iron, but quite erroneous in the case of some ductile materials, which latter sometimes give a work of ultimate resistance amounting to three-fourths or even five-sixths of the product of maximum resistance by the extension.

This accident was thus really caused by the entrance upon the bridge of a load capable of straining the metal to about one-half of its ultimate strength, if slowly applied, but which, in consequence of its sudden application, doubled that stress.

"This sudden action may have been a consequence either of its coming upon the structure at a very high speed, or a result of the loosening of a nut, or of the breaking of a part of either the bridge floor or of one of the trucks of the train. The latter occurrence, permitting the load to fall even a very small distance, would be sufficient."

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* *Trans. A. S. C. E.*, Vol. VII, 1878.

TENSILE STRENGTH OF WROUGHT-IRON BARS, ORIGINAL STRENGTH AND STRENGTH AFTER THE BARS HAD RESTED; ALSO STRENGTH AFTER ANNEALING.—*U. S. Report*, 1882.

No. of Test.	Condition of bar when tested.	Size of bar when tested.			Strains on original section.		Strains on reduced section.		Uniform elongation from original length.	Contraction of area from original section.	Appearance of Fracture.	Remarks.
		Width.	Thick.	Sectional area.	Elastic limit.	Ultimate strength.	Elastic limit.	Ultimate strength.				
		In.	In.	Sq. inch.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs. per sq. in.	Per cent.	Per cent.		
993	Original, ...	3.05	1.00	3.05	29,500	51,150	. . . .	. . . . .	21	31.5	Fine fibrous.	
	Rested four months since original test,	. . .	. . .	. . .	. . . .	60,000	. . . .	. . . . .	24	. . .	Fibrous, 90 per ct.; granular, 10 per ct.	
994	Original, ...	3.05	1.00	3.05	28,500	51,110	. . . .	. . . . .	21	36.1	Fine fibrous	
	Rested four and two-third months, . .	. . .	. . .	. . .	53,440	61,960	. . . .	. . . . .	25	33.8	Fibrous, 92 per ct.; granular, 8 per ct.	
981	Original, ...	3.05	1.01	3.08	28,000	50,390	. . . .	. . . . .	14	35.1	Fibrous.	
	Rested five months,	. . .	. . .	. . .	. . . .	60,390	. . . .	. . . . .	20	21.8	Granular, 70 per ct ; fibrous, 30 per ct.	
973	Original, ...	5.05	1.28	6.46	27,500	50,500	. . . .	. . . . .	13	24.2	Fibrous, 95 per ct.; granular, 5 per ct.	
	Rested eight months,	. . .	. . .	. . .	56,500	58,980	. . . .	. . . . .	18	17.	Fibrous, 30 per ct.; granular, 70 per ct	
	Heated cherry red and cooled in open air, ...	4.75	1.17	5.56	21,670	36,220 41,640	26,080	42,090 48,380	33	. . .	Fibrous, ...	Broke at end of annealed section.
774	Original, ...	3.03	1.01	3.06	29,500	53,630	. . . .	. . . . .	16	36.	Fibrous, 92 per ct.; granular, 8 per ct.	
384	Rested ten months, .	2.84	0.94	2.67	53,920	63,130	61,800	72,360	23	21.9	Granular.	
385	Heated dull red and cooled in open air,	2.80	0.92	2.58	22,800	41,240	27,130	48,910	32	34.0	Dull fibrous.	
777	Original, ...	3.03	1.01	3.06	29,000	53,560	. . . .	. . . . .	15	37.9	Fibrous.	
386	Rested ten months, .	2.87	0.95	2.73	53,920	63,070	60,440	70,696	19	19.6	Fibrous, 10 per ct.; granular, 90 per ct	
387	Heated to 370 degrees and cooled in open air, . . .	2.83	0.92	. . .	57,520	57,520	67,700	67,700	19	34.6	Fibrous, 60 per ct.; granular, 40 per ct.	
	Rested fifteen days after third test, . .	. . .	. . .	. . .	. . . .	62,420	. . . .	. . . . .	. . .	. . .	Fibrous, 60 per ct.; granular, 40 per ct.	
971	Original, ...	3.03	1.01	3.06	32,500	53,500	. . . .	. . . . .	16	27.5	Fibrous.	
388	Rested nine months,	2.84	0.94	2.67	55,880	63,360	64,040	72,620	21	19.9	Fibrous, 30 per ct.; granular, 70 per ct.	
389	Rested nine months,	2.84	0.92	2.61	. . . .	66,010	. . . .	77,400	21	19.9	Fine granular.	

"The same method may sometimes be used to ascertain the probable cause of a boiler explosion by determining whether the metal has been subjected to overstrain in consequence of overpressure. The causes of accidents to machinery may also be thus detected, and many other applications will suggest themselves to every engineer."

Subsequently to the publication of these facts and deductions, experiment showed that strain of the metal in any direction affected the elastic limit measured in any other direction of stress.*

A test-piece, strained in tension, showed exalted elastic limits in compression, torsion, and transverse tests, and a primitive strain in either of the latter directions affected all the elastic limits in the other directions. The permanent effects of strains in metals and their self-registration, like the other phenomena of this class already alluded to, as well as their known mutual interactions, constitute an exceedingly important field of further study and research on the part of the metallurgist and the engineer. It is to this field of study that the writer would invite the attention of such investigators. The exploration of this field has but just begun. In conclusion is introduced the tabulated results of an interesting series of similar determinations made subsequently (1882) at the Watertown Arsenal, upon the great Emery testing machine, purchased by the "U. S. Board appointed to test Iron, Steel, and other Metals," and inherited by the Ordnance Bureau of the War Department.† An extremely valuable and interesting collection of data bearing upon this department of research may be found in the report of that commission, and it may well be questioned whether any more probably fruitful and useful lines of investigation could be found than those which are related to the facts above referred to. They are of real and practical value to the engineer.

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* *Trans. A. S. C. E.*, Vol. XXIV, 1891.

† *Report of U. S. Board*, 2 vols., 8vo; R. H. Thurston, Editor; Washington, Gov't Printing Office, 1878.

ALLOYS OF IRON AND NICKEL.*

By Professor M. Rudeloff.

A SPECIAL committee having been appointed to study the properties of iron alloys, Prof. M. Rudeloff, Assistant Director of the Royal Prussian Testing Department, reported recently to the *Verein zur Beförderung des Gewerbfleisses* on alloys of iron and nickel. Thirteen different mixtures were produced, three ingots from each mixture. The ingots weighed 20 kg. each and measured 15 inches in length, 2½ inches thick and 4 inches wide. Their chemical composition is given in Table I.

CHEMICAL COMPOSITION OF THE IRON USED.

	Iron.	Carbon.	Mang.	Silicon.	Phos.	Sul.	Copper.	Nickel and cobalt.
Per cent., . .	99.710	0.070	0.079	0.013	0.007	0.013	0.068	0.039

CHEMICAL COMPOSITION OF THE NICKEL USED.

	Nickel.	Iron.	Cobalt.	Copper.	Silicic acid.	Carbon.	Sulphur.	Alkalies Lime and alumina.
Per cent., ...	98.21	0.25	1.19	0.07	0.24	Trace.	Trace.	Trace.

PERCENTAGE OF NICKEL AIMED AT IN EACH GROUP OF THREE INGOTS—INGOTS NOS. 1–3 WERE PURE IRON; NOS. 37–39 PURE NICKEL.

Ingot No.	1–3	4–6	7–9	10–12	13–15	16–18	19–21
Per cent. of Nickel, . .	0.00	0.50	1	2	3	4	5
Ingot No.	22–24	25–29	28–30	31–33	34–36	37–39	
Per cent. of Nickel, . .	8	16	30	60	95	100	

The method of melting the material was uniform in all cases. The fuel used was coke and the melting was done in graphite crucibles. Before pouring, a small amount of aluminum, or magnesium, or ferromanganese was added to make the metal more fluid. At first the inside of the mold was washed with chalk. This proving objectionable, causing checks and rough surface of the ingots, a clay wash was substituted with better results.

The pure iron, and mixtures rich in iron, required the addition of 20 gm. of aluminum to 20 kg. of metal to produce the required fluidity for casting. On the other hand, 10 gm. of magnesium prevented spongy ingots with the nickel, or mixtures rich in nickel. For the purpose of chemical analysis the ingots were sawed in two and the surface planed. The chips thus obtained were then used for chemical analyses. The strength of the alloys produced was ascertained by tensile and shearing tests, by slow compression and crushing under the drop. Three test-pieces from each ingot for each kind of test were prepared. The degree of expansion by heat was determined on four ingots, one of pure iron and pure nickel each, and one with 4 and 16 per cent. nickel respectively. By the tensile test the elastic limit, yield point, breaking strength, and elongation were determined. Average results of tests are given in Table II. In Table III the proportional strength of alloy to pure iron is given, the iron being taken as 100. In the compression tests the yield point was determined and the percentage of reduction from the original height, under a load of 160,000 pounds per square inch. Results are found in Table IV.

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* From the *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses.*

In the drop tests, 20 blows were given with a drop weighing 125 pounds, falling 9¼, 18½, 37 inches respectively. Results are given in Table V. Shearing tests were made by inserting the test-pieces in suitable holes of hardened steel washers, two of which were recessed in suitable blocks, one in each block, while a third washer sliding between the other two served as a shear by being forced down by means of a shear plate encircling the washer partly, and upon which pressure was exerted. Results are given in Table VI.

SUMMARY OF RESULTS OF TESTS.

Expansion by Heat.—The coefficient of expansion by heat was found to decrease with the increase of percentage of nickel, but was greater with the 98 per cent. nickel than with the pure iron. Taking the value of pure iron as 100, the difference in expansion was:

	Per Cent.
Iron and 4 per cent. nickel —	5.7
Iron and 16 per cent. nickel —	10.9
Iron and 98 per cent. nickel +	9.1

Or 94.3, 89.1, and 109.1 respectively.

Chemical Analyses.—A detailed examination of the analyses warrants the conclusion that the addition of nickel to iron does not appreciably influence the chemical contents of the iron in foreign elements. On the other hand, all foreign elements in the nickel are also found in the iron-nickel alloy.

TABLE I.

RESULTS OF CHEMICAL ANALYSIS OF INGOTS. AVERAGE OF THREE INGOTS.

Percentage of Nickel Aimed At.	Per Cent. of Iron.	Per Cent. of Nickel.
0.00	99.59	0.05
0.50	98.99	0.76
1.00	98.75	1.01
2.00	97.72	2.05
3.00	96.63	3.00
4.00	95.81	3.98
5.00	94.81	4.92
8.00	91.89	7.84
16.00	84.12	15.59
30.00	69.74	29.77
60.00	39.69	59.60
95.00	5.15	93.68
100.00	0.33	98.89

Tensile Tests.—The elastic limit, yield point, and breaking load rise until the percentage of nickel reaches about 10 per cent. Thence a decrease takes place of these values, until the nickel reaches 30 per cent. With a further increase of nickel the elastic limit and yield point decrease still more, while the breaking load is higher with 60 per cent. nickel than with 30 per cent., whence it decreases again.

The elongation decreases as the percentage of nickel increases, and is almost zero at 16 per cent. nickel. From there on elongation increases until with 60 per cent. nickel its maximum is reached, declining then with increase of nickel.

It will be seen that the elastic limit and yield point of pure nickel is only about 60 per cent. of the pure iron, the breaking load of the two metals are nearly the same, while the elongation of pure nickel is about 60 per cent. of that of the pure iron.

The elastic limit is raised highest by the addition of nickel, next the yield point, and then the breaking strength. The structure of the metal is likewise changed with changes in the percentage of nickel. In the pure iron the structure is amorphous. With 0.5 per cent. nickel the tensile fracture begins to get granular. With 5 and 8 per cent. nickel the structure is pronounced crystalline, the crystals assuming the shape of needles with 16 and 30 per cent. nickel, this structure continuing to the end of the series. With 0.5 per cent. nickel the ingots have a tendency to be honeycombed. They become sound with 1 per cent. nickel, continuing to be so up to 30 per cent. nickel, when the ingots exhibit oxidation in their interior.

TABLE II.

AVERAGE RESULTS OF TENSILE TESTS.

Per Cent of. Nickel.	Elastic Limit, Lbs. Per Sq. In.	Yield Point, Lbs. Per Sq. In.	Breaking Strength, Lbs. Per Sq. In.	Elongation, Per Cent. in 2 In.
0.05	8,535	20,768	46,100	29.7
0.76	8,819	22,617	45,652	20.6
1.00	10,242	23,613	47,938	26.4
2.05	14,500	28,734	52,632	22.7
3.00	22,900	34,144	57,753	20.1
3.64	23,630	28,265	57,750	17.6
4.93	27,881	46,230	63,443	10.8
7.84	32,433	62,874	79,944	9.6
15.60	22,760	. . .	58,322	0.6
29.78	8,962	17,781	14,225	2.2
59.66	8,535	17,780	53,770	36.1
93.55	5,832	15,363	47,221	19.0
98.56	5,121	12,944	43,386	17.1

TABLE III.

PROPORTIONAL STRENGTH OF ALLOY TO PURE IRON, TAKING IRON AS 100.

Per Cent. of Nickel.	Elastic Limit.	Yield Point.	Breaking Load.	Elongation in 1 Inch.
0.0	100	100	100	100
8	380	303	173	30
16	267	280	126	2
30	105	86	31	8
60	100	86	117	103
98	60	62	94	50

Compression Tests.—The resistance of the alloys to compression does not seem to differ in different parts of the ingot. The resistance increases steadily until 16 per cent. nickel is reached, whence it begins to decrease until at 94 per cent. nickel the resistance is only 50 per cent. of the pure iron. There is a small increase again with 98 per cent. nickel. Thus, generally speaking, the behavior of the alloys under compression is similar to their behavior under tension.

TABLE IV.

AVERAGE RESULTS OF COMPRESSION TESTS.

Per Cent. of Nickel.	Yield Point. Pounds Per Sq. In	Per Cent. of Reduction of Test-Piece Under a Head of 160,000 Pounds Per Square Inch.
0.05	25,900	47.8
0.56	22,500	47.4
1.01	28,300	45.5
2.06	37,200	42.1
3.01	40,700	38.8
3.98	40,100	37.5
4.92	54,900	34.1
7.84	72,500	29.2
15.60	163,700	0.7
29.78	30,300	37.5
59.60	22,900	33.1
93.52	13,900	34.6
98.89	18,000	36.9

Drop Tests.—The results of drop tests are more or less a repetition of the metal as exhibited in the compression tests. The strength increases up to 16 per cent. nickel, reaches the value of pure iron with 30 per cent. nickel, remaining in that condition to the highest percentage of nickel in the alloy.

TABLE V.

AVERAGE RESULTS OF DROP TESTS.

Per Cent. of Nickel.	Per Cent. Reduction of Test-Piece.		
	Distance of Weight Falling, 9¼ Ins.	Distance of Weight Falling, 18½ Ins.	Distance of Weight Falling, 37 Ins.
0.15	64.7	76.0	84.4
0.56	(63.3)	(76.7)	. . .
1.01	63.6	76.2	83.3
2.05	60.7	75.8	81.7
3.00	57.6	73.5	82.0
3.98	58.0	72.9	80.4
4.92	54.9	71.8	81.1
7.84	51.6	68.7	78.7
15.59	(25.3)	(46.7)	70.0
29.77	60.0	72.7	80.4
59.60	56.2	71.1	78.7
93.68	(58.0)	(71.9)	78.7
98.39	60.0	72.7	80.4

Figures in parentheses represent averages of less than three tests.

Shearing Tests.—The phenomena exhibited by the metal under shearing tests are very much like those observed at the yield point when the metal is under compression.

TABLE VI.

AVERAGE RESULTS OF SHEARING TESTS.

Diameter of Test-Pieces.		Diameter of Test-Pieces.	
Per Cent. of Nickel.	Load Applied to Shear in Lbs. Per Sq. In.	Per Cent. of Nickel.	Load Applied to Shear in Lbs. Per Sq. In.
0.05	37,800	7.84	61,870
0.56	36,800	15.60	96,300
1.01	40,400	29.78	50,200
2.06	43,400	59.60	53,900
3.01	47,400	93.52	50,800
3.98	49,100	98.39	49,400
4.92	52,000		

COMPARATIVE ANALYSIS

OF THE RESOLUTIONS OF THE CONVENTIONS OF MUNICH, DRESDEN, BERLIN, AND VIENNA, AND THE RECOMMENDATIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, WITH THE CONCLUSIONS ADOPTED BY THE FRENCH COMMISSION IN REFERENCE TO THE TESTING OF METALS.

Report presented by M. L. Baclé, Member of the French Commission on Methods of Testing Construction Materials.

[Translations from the French and from the German by O. M. CARTER, Captain Corps of Engineers, U. S. A., and E. A. GIESELER, U. S. Assistant Engineer.]

INTRODUCTION.

TWO attempts have been made abroad to secure the adoption of uniform methods of testing construction materials—one under the auspices of technical conventions held at different times in Munich, Dresden, Berlin, and Vienna, where, besides the German members, there were present delegates representing various foreign countries; the other, in America, under the auspices of the American

Society of Mechanical Engineers. Two reports presented to the Committee of Research, one by M. Polonceau and the other by M. Baclé, have given translations of the conclusions and recommendations thus adopted by the Conventions and by the American Society.

It is proper, therefore, to make a comparison between the resolutions adopted by foreign conventions and those adopted by our own commission, in order that we may examine the differences and analogies which they present. Such a comparison affords an opportunity of deciding whether there should be renewed study and research upon the points of difference, and of determining whether we may hope for international unity in the future, based upon the common resolutions already recommended and even now adopted in the current practical domestic relations of different countries.

The work of comparison in the present report, intended in some measure to form a starting point for the studies of an international commission which might be created for this purpose, has been confined to the methods of testing metals, which is the sole subject of discussion in Section A. (Section des Métaux.)

To facilitate comparison, avoiding as much as possible all omissions, an attempt has been made to place together all resolutions relating to the same subject, and to this end the methods of classification used in our General Report have been adopted. The present report follows, therefore, the divisions and rules of the General Report, giving under each chapter only such resolutions as offer a possibility of comparison with the corresponding foreign recommendations.

The comparison is usually made by referring to the resolutions of the Conventions, for those are frequently reproduced in the recommendations of the American Society. In certain cases, however, those two groups of resolutions present differences which then become the subject of special mention.

It is advisable to point out in a general way, among the resolutions to be compared, a primary difference in principle (which is, however, of little real importance) relating to tests made upon finished pieces. The resolutions of the Conventions, identical in this respect with the resolutions of the American Society, define the tests which should be made upon certain articles in current use, such as tires, axles, and rails. For certain kinds of metals, such as wrought or cast iron, for different specified uses, they advise the discarding of such tests as to them seem unnecessary, while our commission refuses to make any such elimination, feeling totally unauthorized to do so.

With regard especially to methods of testing, the studies of our Commission have been more general than those made abroad, and the recommendations that we have made include various kinds of tests not mentioned in the foreign resolutions, with which, therefore, no comparison is possible.

On the other hand, certain methods of testing have been especially recommended in all of the resolutions, such as tensile, shock, and bending tests, and it is with respect to those that the committee should make special comparative examinations.

In tensile tests the Conventions do not define so definitely as do we the quantities to be measured; they do not give the same limits of approximation in their measures; they follow the law of similarity in adopting cylindrical test-pieces, but use a different coefficient from ours, which tends to give to the useful or test length a greater value for the same diameter. Other differences are apparent in the description of their standard rectangular test-pieces.

The American Society prescribes an invariable standard of test length, independent of both the diameter and the cross section of the test-piece.

The resolutions of the Conventions concerning shock tests are confined almost entirely to finished pieces. They give more explicit directions than do we in regard to the arrangement of the apparatus employed, but certain experiments made upon test-pieces that we have especially studied are not mentioned by them.

In bending tests they recommend that the bending should be done around a mandrel of unvarying diameter, while the American Society claims that the mandrel should vary in proportion to the thickness of the test-piece. The dimensions of their bars differ also from those used by us.

The differences just given are the most marked; but they are in reality of little importance, and probably can be easily overcome.

In the general resolutions concerning the precautions to be observed in preparing test-pieces we find at times differences of detail, but they are usually of minor importance, since the three sets of resolutions upon that subject are inspired by the same general principles.

In so far as the general formulas, as well as the methods of testing referred to above are concerned, we find as a result of this comparison nothing to indicate that the desired unity of method may not be attained should an international commission be called for that purpose.

FIRST AND SECOND PARTS.

PHYSICAL EXAMINATION AND CHEMICAL TESTS.

The resolutions of the Conventions do not contain any specific directions upon those subjects, but they advise the acquisition of as thorough a knowledge as possible of the results of both microscopic and chemical examinations, especially in all cases of scientific research.

According to the recommendations of the American Society, the magnetic condition of a metal should be especially mentioned.

Those recommendations require, moreover, that when in tensile tests the ruptured section presents a cupel form the fact should be mentioned, the relative position of the edges of the cupels with reference to each of the pieces of the tested bar being indicated.

To determine the effects of tempering upon steel, the American Society recommends in addition that the bars should be heated to a bright red and immediately quenched in water at from 32° to 40° F. (0° to 5° C.).

Our Commission requires that the test-bars should be heated to a comparatively deep cherry red and quenched in water at 28° C., the volume of water being great in proportion to the volume of the bars.

The resolutions of the Conventions also require that the metal should be heated to a cherry red (placed by them at from 550° to 600° C.) and quenched in water at 25° C.

They recommend also, as will be seen later on, that copper test-pieces should be heated to 700° C. and quenched in water at 15° C.

That recommendation is not found among our conclusions, which require, however, that deductions from experiments with copper or its alloys shall be drawn from tests made after the last annealing in the manufacture of the plates.

THIRD PART.

MECHANICAL TESTS—RECOMMENDATIONS COMMON TO ALL METHODS OF TESTING.

Chapter I.—General Observations.

Our resolutions show the importance of accompanying mechanical tests of whatever nature with the tensile test; they indicate the approximate exactitude with which one should be content in the majority of current tests, by showing that in practical experiments the exaggerated precision required in scientific research is not necessary. They avoid, moreover, giving any indication regarding a choice between the various methods of testing according to the application proposed.

The resolutions of the Conventions recommend generally that testing should be done with reference to the work to which the pieces are to be subjected; at the same time they indicate which test to adopt and which to reject in specified cases; they advise the adoption of regular tests for certain pieces frequently employed, such as rails, tires, and axles for railroad use, cast or wrought iron, materials for shipbuilding, etc., recommending the greatest possible number of tests upon all pieces of the same delivery, testing without damaging them.

They recommend, for instance, testing tires and axles by shock with a standard impact machine, claiming that it is useless to test tires by a hand hammer or axles by flexure. They add that it may be advisable to have recourse to tensile tests to obtain certain additional complemental information.

They confine themselves to recommending that the degree of exactitude attained in the tests should be stated, or at least that data should be furnished allowing it to be determined.

The resolutions of the American Society recommend that tests should be made as far as possible upon the pieces themselves whose quality it is desired to ascertain, being careful to reproduce as far as possible the conditions to which the pieces will be subjected when in use. They add, with a view to facilitate comparison, that it would be well to make a standard test over and above the tests upon finished pieces.

With regard to registering apparatus, our Commission limits itself to saying that it should be employed without hesitation, as its use even when it is not positively accurate may prevent serious error.

The American Society seems, however, to recommend it more formally, especially for tensile tests.

In regard to test-pieces that are imperfect, our resolutions require that they shall be thrown out of the calculation of averages established from a scientific point of view whenever there are exceptional or local defects in the test-pieces.

The American Society remarks on this subject that in making tests all pieces of abnormal appearance or those showing superficial defects should be rejected. If, however, a perfect piece cannot be found, a record of the imperfections should be kept.

CHAPTER II.—PREPARATION OF TEST-PIECES.

CONDITION OF THE METAL.

Our resolutions recommend in general that the condition of the metal employed shall be precisely defined principally with respect to hammer hardening (*ècrouissage*)*, and especially when soft metals are used, that the test-pieces shall not be removed until the metal has been brought to the exact condition under which it is decided to test it; they mention also the precautions to be taken in finishing off test-pieces, in order to avoid any strain which might produce a change in the condition of the metal.

The American Society also insists upon the importance of observing its resolutions, which state that the lightest blow from a hammer, or any blow incorrectly given, may falsify results, should the abnormal strain thus produced be greater than that required to cause variation in the quality of the metal to be tested.

They admit, moreover, that soft metals are less susceptible to those influences than hard metals.

With regard to plates of mild steel, the Conventions have decided that it is unnecessary to test them after they have been annealed, as it is too difficult to determine the exact temperature of annealing. They add, in conclusion, and in accord with our Commission, that the object generally sought is to ascertain the nature of the metal in the condition when delivered.

THE PLACE AT WHICH AND THE MANNER IN WHICH TEST-PIECES SHOULD BE CUT—FABRICATION OF TEST BARS.

The resolutions of the Conventions require, for instance, with rails, that the bars detached shall have square † sections and contain the exterior fibres of the rail. Our advice is in general to take the test-bars from the thinnest and thickest parts of the complicated rolled section.

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* Hammer or cold hardening (*ècrouissage*) is an alteration produced by working a metal when cold with a hammer, a die, a punch, shears, etc. *Écrouissage* is the standard change in a metal which has been subjected to a permanent deformation at a temperature lower than that required for annealing.

† The original resolutions require only a *rectangular* section.—O. M. C.

With regard to plates, the resolutions of the Conventions are imbued with the same spirit as ours, from which they vary only in minor details. They advise taking the test-pieces from the longitudinal and transverse sides, cutting away, when raw or uncut plates are used, at least 30 millimeters in width from the exterior; when dressed plates are used the test-pieces should be chosen from plane plates of regular thickness.

They admit, without going further into details, that the strips should be cut with shears or by a saw, but for bridge iron or boiler plates they require that the strips cut off by shears shall be straightened out cold by a press, by the use of a wooden mallet, or by small hammers of lead or copper. Before cutting out the test-pieces the strips should be planed down on each side for a width of at least 5 millimeters to do away with the effect of the shears. Upon express demand annealing is permitted for straightening out strips cut by shears from boiler plates.

Our resolutions impose more minute precautions to prevent the deformation of the bars, and if annealing is indispensable for straightening, they require that a temperature of 700° C. shall not be exceeded.

They require also that the test-pieces shall be cut from the strips by a machine, without, however, stipulating that a depth of 5 millimeters in thickness of the metal shall be removed.

For rolled products, the resolutions of the Conventions prescribe that the rough rolled surfaces shall be preserved. Our instructions do not mention that point, but it may be observed that in practice that method is always followed.

The Conventions require, finally, that the reports of tests shall make known the source and the method of manufacture of the test-pieces, and they add that those pieces designed for compression tests should, as far as possible, be smoothed by planing or turning.

In the preparation of test-pieces of copper, they recommend the most minute precautions, which are also mentioned in our resolutions.

Besides those, they add, as has been indicated above, that bars of copper should be annealed at 700° C.* before they are completed, then cooled in the air to a dull red, and finally quenched in water at 15° C., while our resolutions demand that tests shall be made after the last annealing in the fabrication of the plates.

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* That temperature must not be exceeded. *Vide* Original Resolutions.—O. M. C.

In regard to test-pieces of cast iron, the Conventions require that they shall be cast in a mold of very dry sand having an inclination of 10 centimeters per meter.

The entrance for the flow of the melted material should be placed 20 centimeters above the mold, determining thus the length of the runner stick. Those test-pieces should be left with the rough surfaces produced by the molds.

Our resolutions require that for pieces which at some places are more than 9 centimeters thick the test-bars should be cut by a machine from the foot of the runner stick. For other pieces the test-bars may be cast separately, if care be taken to give the mold an inclination of about 20 centimeters per meter and to make the runner stick from 15 to 20 centimeters long.

They always discard the runner stick for bars cast in contiguous pieces.

The American Society remarks, without stating any general laws, that the superficial crust found upon raw materials, either rolled or cast, is either an advantage or a hindrance, according to the work in view, and should therefore be taken into account in the preparation of test-pieces.

CHAPTER III.—STUDY OF THE INFLUENCE OF TEMPERATURE UPON THE RESULTS OF TESTS.

Our resolutions point out the precautions to be observed in making tests at any given temperature, high or low; afterward they deal especially with tests made at ordinary temperatures, remarking that the influence of variations in temperature is felt principally in shock tests, and giving directions for the mitigation of the same.

The resolutions of the Conventions do not contain any directions with regard to those tests; they require that in the cold bending of copper bars the temperature shall not be less than 10° C.

CHAPTER IV.—STUDY OF THE INFLUENCE OF DURATION.

Our Commission gives no positive rule with regard to the effect of the duration of test, considering that the subject is not as yet sufficiently understood; it recommends, however, the continuance of study upon that subject.

The Conventions declare for their part that the influence of time is incontestable, especially in tracing the diagrams in tensile tests, but they conclude that as yet they have not sufficient ground for establishing any fixed velocity of testing iron, copper, and bronze.

On the other hand, in cold-bending tests they claim that the duration is of no importance. In operating upon heated materials they require that the tests shall be made as rapidly as possible, but this is doubtless in consideration of the cooling of the bar.

The American Society requires that the duration of tests shall be noted.

CHAPTER V.—GENERAL OBSERVATIONS UPON TESTING APPARATUS.

APPARATUS OPERATING BY GRADUAL ACTION.

MACHINES FOR TENSILE TESTS.

The Conventions confine themselves to demanding that machines properly handled shall not produce any shock on the test-pieces. They sanction the use of machines operated by hydraulic pressure or by a screw. They add that the test-pieces should be so mounted that the strain of tension or compression shall be uniformly distributed throughout the cross-section.

Besides those requirements, which coincide with those of our Commission, the Conventions include in their resolutions more explicit directions as to the mode of fastening the test-pieces for tensile tests than do we.

For cylindrical test-pieces they propose the use of spherical bearings, preferably in one piece.

They agree that test-pieces of rectangular cross-sections shall be held at each extremity by a bolt passing through a slot provided for the purpose, or that the pieces shall be provided with milled heads and clamped by proper wedges.

They forbid positively the use of the serrated wedges used by us, and that point should be submitted to a renewed examination by us.

This last resolution is also adopted by the American Society, which, moreover, recommends in positive terms the use of two special types of attaching apparatus in use in the United States.

With regard to round test-pieces, the American Society proposes to prolong the cylindrical section by conical bearings resting upon the clamping pieces, in preference to threaded ends, such as are often used. This form is recommended for all metals except copper and its alloys, for which the Society considers it as yet impossible to give any standard type, conclusive experiments being lacking.

MACHINES FOR PRESSURE TESTS.

The Conventions in their resolutions are in almost perfect accord with us upon this subject. They require that the strain shall be carefully distributed throughout the cross-section, and point out that to attain such a result it is well so to place the pressure plates that at least one may move easily and freely in all directions.

Those resolutions recommend, moreover, the use of very smooth test-pieces; in other words, those which have been planed or turned; but this recommendation has reference only to the bearing surfaces, since in speaking of castings they require besides that the faces of test-pieces for flexure and compression shall be left in the rough state.

The American Society requires that the pieces to be tested shall be placed in position without the aid of any intervening medium whatsoever, such as wedges, supporting discs, etc., and that they shall be brought exactly into the axis of strain. That Society repeats that the test-pieces should be prepared with the utmost care, the bearing surfaces being exactly parallel and normal to the axis.

Whenever tests are made upon large pieces horizontally placed it is necessary to take into account the initial flexure due to the weight of the piece as held in place.

MACHINES FOR TRANSVERSE, FOLDING, BENDING, AND CURVING TESTS.

The Conventions confine themselves to recommending slow-moving apparatus, acting either by pressure on the middle between two supports or by lateral pressure brought to bear upon one part of the test-piece, while the other is securely held by clamping. Such apparatus should be simple and capable of being used rapidly. The weakest part of the test-piece should be clearly visible.

For folding, they simply indicate that it should be done in a continuous manner, and that if a mandrel is used it should be of the smallest possible diameter, recommending in certain cases one with a fixed diameter of 25 millimeters. They repeat, moreover, that the angle of bending is not alone sufficient to indicate the deformation, but that the radius of external curvature must be taken into account.

The American Society recommends the use of a very simple apparatus for making bending tests upon mandrels of varying diameter, and prescribes the use of the hand vice for bending, which is accepted by us, however, with certain restrictions.

For transverse tests that Society advises that supporting wedges shall not be used, preferring rolls that shall be displaced in proportion to the deformation by flexure of the bars.

The foreign resolutions do not point out the different modes of testing by bending that are specially defined by our Commission, but the Conventions state that the permanent committee should seek to determine, in the comparative tests remaining to be executed, the best method of measuring deformations.

MACHINES FOR TORSION TESTS.

According to our conclusions, those machines should be arranged in such a manner that the axis of the piece will not sustain any flexure.

The resolutions of the Conventions give no data upon this subject, but the American Society has given definite instructions tending to prevent the production of any disturbing strains, such as transversal flexure or longitudinal tension over and above torsion properly so-called. To this end the collars which hold the test-pieces should be exactly concentric with it, to avoid giving any but a tangential strain.

APPARATUS OPERATING BY ABRUPT ACTION.

The resolutions of the Conventions are generally in harmony with ours in principle, but they give much more explicit directions for the setting up of testing hammers, especially in the case of heavy machines intended to test whole pieces. They have adopted for this purpose, as a standard type of hammer, one weighing 1,000 kilograms, permitting in certain exceptional cases the use of one weighing only 500 kilograms, and they have decided that every hammer of the standard type shall be stamped and officially registered. They require that the studies relating to the question of shock tests shall continue, and they have charged the permanent committee with collecting all new propositions relating to the installation of machines for shock tests.

They accept hammers as we make them, of cast iron or of cast or forged steel; they add that the striking surface should be of forged steel, finished by dove-tailing and made secure by wedges in such a manner that the vertical centre of gravity of the whole may not be disturbed.

This vertical should coincide with the axis of the leads and should be indicated by marks upon the anvil or the anvil block. The proper arrangement of the striking surface should be verified by means of suitable reference points.

We require, moreover, that the mass and shape of the hammer shall be perfectly symmetrical with respect to the plane of the leads.

Our directions, more especially with reference to tests upon test-pieces, regulate the form of the face of the small hammers used, and they indicate even the radius of curvature to be given that face, depending on the kind of metal to be tested. They also give the different weights for such hammers used under similar circumstances.

According to the resolutions of the Conventions, the guided length of the hammer should be at least double the clear width between the guides; we claim, however, only that it should be greater than the width between the guides.

The Conventions require that the weight of the anvil block shall be at least ten times that of the hammer, and that the foundations shall be inelastic. We require that the anvil block shall constitute, either alone or embedded in solid masonry, a solid mass from fifteen to twenty times heavier than the hammer.

In the working of the detaching apparatus the Conventions agree with us that there should be no wedging. The Conventions advise the placing of the point of suspension upon the same vertical as the centre of gravity of the hammer, and to intercolate between the detaching device and the hammer a short flexible piece—for example, a chain or cord. They point out as a style to be recommended the detaching device adopted in Russia, which, however, from the sketch given, does not seem to be provided with an intermediate chain or cord.

In regard to the friction on the leads, they recommend that those leads should be lubricated with plumbago. They reject all apparatus having a work due to friction greater than 2 per cent. of the useful work. They describe a process of measuring friction by intercolating a spring balance between the hammer and its lifting rope. They propose to deduce the effective weight of the hammer from the effect produced, with a given height of fall, on a centrally mounted standard cylinder made of copper, of dimensions yet to be determined.

For the height of fall they advise that 6 meters shall not be exceeded, as the setting up of hammers of greater height cannot be done with as much security or exactitude. They recommend the use of a sliding scale for measuring the effective work, so that the zero of the graduation may be set at the top of the piece to be tested. That scale should be divided into metric half tons.

All of the recommendations of the Conventions with regard to the setting up of machines for shock tests are agreed to by the American Society; the weight of the hammer and the height of fall are determined by the measures in use in America. The weights adopted are, respectively, 1,000, 1,500, and 2,500 pounds for testing large pieces (equal to 453, 653, and 907 kilograms), and the height of fall is fixed at 20 feet (equal to 6.09 meters), allowing, however, without doubt, the adoption of a less height of fall in special cases.

CHAPTER VI.—EXAMINATION OF THE FORCES TO BE MEASURED.

Our resolutions recommend in effect that the strains and deformations produced in all tests by continuous action shall be measured; these form of necessity two great classes—the one of elastic and the other of permanent deformation.

Concerning the period of elastic deformation, three limits of elasticity are distinguished and defined, viz., the theoretical, the proportional, and the apparent. Concerning the period of permanent deformation, our resolutions define the maximum load supported, and the load of rupture, properly so-called, giving the deformation corresponding to each of those two loads.

Neither the resolutions of the Conventions nor those of the American Society give any instructions common to all tests made by gradual action; they restrict themselves entirely to tensile tests.

The Conventions require that during the elastic period there shall be sought the yield point and the limit of proportional elongation, appearing at the same time to admit that those two limits are blended, and during the period of permanent deformation the maximum resistance and the beginning of contraction as well as the load of actual rupture with the corresponding section.

The American Society requires the determination of the same information, excepting only the beginning of contraction, insisting especially upon the importance of the yield point, which measurement it claims should be made with the greatest precision.

It defines that limit as being the load which produces a modification in the rate of elongation, which would seem to identify it with the proportional limit; but further on, in an annexed illustration, it requires that the limit shall be determined by noting the point at which the elongation is suddenly augmented, which brings us back to the apparent limit.

The recommendations of that Society prescribe, moreover, the measurement of the elastic elongation with a view of determining thereby the modulus or coefficient of elasticity, and they point out, to this end, a special process consisting of measuring the elongations between certain limiting loads, determined in advance.

They also observe the smallest section of the test-piece under the action of the elastic limit (yield point), and, after the test, the section of rupture.

In the calculation of the strain brought to bear upon the unit of section, their resolutions add that it is necessary always to consider the initial appearance of the test-piece, and not the constantly-changing appearance under the different loads that it supports up to the limit of rupture.

This resolution conforms with that of our Commission. However, as in experiments made upon copper and brass, a comparison of the loads developed in the course of the tests with the corresponding deformations has given rise to interesting conclusions, our Commission has expressed the hope that analogous studies shall be made in regard to iron and steel.

CHAPTERS VII AND VIII.—MECHANICAL AND TECHNICAL TERMINOLOGY.

Those two questions have been examined by our Commission only, but we have not been able to establish any fixed laws in regard to them. They have not been considered by either the Conventions or by the American Society.

FOURTH PART.

DETAILED STUDY OF THE DIFFERENT METHODS OF TESTING.

FIRST CLASS.—METHODS OF TESTING BY GRADUAL ACTION.

Our Commission states in a general way that those tests should be made in a manner as continuous and as regularly progressive as possible, and that recommendation is in accord with that adopted by the Conventions with regard to tensile tests.

The American Society agrees to this also in a general way, but it provides for stopping the strain at certain intervals, whenever it is necessary to make observations of deformation, which is the case, for instance, in measuring the elastic limit and the elastic elongation.

The Society requires in such cases that the developed strain shall never be diminished, but that it shall be maintained continuously in action.

CHAPTER I.—TENSILE TESTS.

MEASURE OF STRESS AND ELONGATION.

Our resolutions define the precision to be sought in the definition and scientific observation of the first two elastic limits previously described; they point out that for such purpose the elongations should be measured to the nearest thousandth of a millimeter.

Such precision is unnecessary for the determination of the third limit, called the apparent limit, or the beginning of great deformation under a constant load.

Regarding the observations made during the period of permanent deformation, our Commission recommends that the maximum load that can be borne shall be measured, saying that it does not appear to be necessary to measure the load of rupture, while, as has been shown heretofore, this measurement is required by the Conventions and by the American Society.

In regard to measuring elongation, our Commission believes that for current practical tests on products of the same well-known make it is sufficient generally to measure the total elongation after rupture; but in more exact tests it would be useful to make some special experiments with a view to determine the relative value of the different parts which compose the total elongation (distributed elongation and elongation of contraction).

The foreign resolutions do not consider this distinction. They recommend simply a method of measuring the total elongation suitable for reducing the results to uniformity by disregarding the influence that the position of the section of rupture beyond the middle of the test-piece may have upon the effective length of the observed elongation. This method amounts in principle to doubling the measured elongation for a distance equal to one-half the length of the test-piece, counting from the section of rupture on the side, where it is possible to measure it, in such a manner as to render the same conditions as would have obtained had the rupture occurred in the middle of the test-piece and had the elongation been produced freely on both sides. The result is to increase a little the effective elongation measured directly on the real test-piece.

This method is inconvenient in that it is necessary in advance to divide the useful or test length into very small sections. The length of each section is fixed at 1 centimeter in Germany and at a half or even a quarter of an inch in America (12 or 6 millimeters). As the elongations during the course of the test are produced in a comparatively irregular manner upon the length of the test-piece, we may consider that they are not necessarily uniform at the ruptured section even when that is in the middle of the piece, and the method can give in this respect only approximate results.

It is true that if recourse to that method is not desired it will be found necessary, according to our resolutions, to discard every test-bar whose elongation of contraction is not integrally included between the reference points; the resolutions of the Conventions, particularizing still further, give this same injunction when the section of rupture falls beyond the middle third of the useful length.

In regard to tensile diagrams, our resolutions declare that it does not seem necessary to have recourse to them, at least in current practical tests with a view to ascertaining the quality of the metal tested from a determination of the useful surface they present.

The resolutions of the Conventions provide, however, for the use of diagrams, and require that their area shall be calculated up to the limit corresponding to rupture. They observe on this subject that without doubt, in principle, the work on the test-piece should be considered only up to the beginning of contraction, but that in most cases the work corresponding to that last period is of little importance, and the error thus produced cannot be very considerable. In cases where the diagram is not made by special apparatus, they advise making as many observations as possible during the test in order to trace the diagram by separate points.

The resolutions of the American Society also provide for the use of such diagrams.

With regard to the varying coefficients thus far proposed, our Commission finds it impossible to recommend them, and, moreover, the foreign resolutions make no mention of them.

In regard to the precision to be sought in measuring strains and elongations, our Commission declares that for strains less than 5,000 kilograms a determination to within 25 kilograms is sufficient, going up to the limit of 50 kilograms, when the strain exceeds 5 tons; or, for the first class, to within one two-hundredths, and for the second to within less than one one-hundredth of the total sum.

The Conventions state that on their part they will accept an error of one-tenth of a kilogram per square millimeter for tensile strains corresponding to the elastic limit (yield point) and to that of rupture, which leads in practice, especially for the load of rupture, to a much smaller proportion of error than we have permitted.

The American Society makes no recommendation upon this subject.

In measuring the dimensions of test-pieces and elongations our Commission recommends a determination to within five one-hundredths of a millimeter in the case of dimensions equal to or less than 10 millimeters, and it accepts an approximation to within one-tenth only when the length to be measured is greater than 10 millimeters; the limit is, therefore, to within more than five one-thousandths in the first case, and to within less than one one-hundredth in the second.

The resolutions of the Conventions recommend a degree of precision reaching one one-thousandth in measuring the elongation of rupture, and of one one-hundredth in measuring the contraction of area (considered, no doubt, as being the section of rupture itself).

They recognize, however, that in many cases these decimals are uncertain, and that it is not necessary to add others. They state that it is sufficient to take the dimensions of test-pieces to within one-tenth of a millimeter, which, considering the measurement of the thickness and the width of the section, gives a degree of precision inferior to that recommended by our Commission.

They require that the elongation shall be measured on two diametrically opposed sides of the test-bar, in order that the mean may be taken of the sum of the lengths obtained by measuring upon each part respectively the distance comprised between the corresponding reference point and the section of rupture.

For rectangular test-pieces it is even proposed to make three measurements of elongation, taking them upon the two sides and upon one of the faces. The mean of the first two measures should be given and the last one should be stated separately.

The General Report of our Commission only mentions the use of elasticimeters, which are considered almost indispensable in determining the elastic limit (yield point), but which seem less necessary for the simple measurement of the total elongation.

With the aim of measuring the section of rupture with all possible precision our resolutions propose that the measurement of the dimensions shall always be made at two opposite points, and that there shall be considered either the circle of mean diameter or the rectangle of mean dimensions, according as the test-pieces have circular or rectangular sections.

DIMENSIONS OF TEST-PIECES.

In order that the proximity of the heads shall not interfere with the observed results, especially in the measurement of elongation, our resolutions require that the distance from the springing or end of the heads to the reference points must be equal at least to the diameter or to the greatest side of the transverse section of the test-piece; they consider that under such conditions the form of the heads is not important.

The Conventions limit themselves to remarking that for cylindrical test pieces the actual length of the cylindrical part should exceed the test length by at least 10 millimeters,* which may be interpreted, doubtless, as imposing a uniform minimum of 5 millimeters of waste length at each end, regardless of the diameter of the test-piece, which may be 10, 15, 20, or 25 millimeters.

The American Society gives regulations analogous to those of the French Commission. It requires that with round test-pieces the distances reserved beyond each reference point shall be equal to or greater than a diameter. For flat or built-up square test-pieces its regulations require once and a half the width of the section or the side of the square.

In order to make a comparison of the total elongations, taken after the rupture of circular test-pieces of different design, our Commission has decided to establish a fixed relation between the transverse section and the useful or test length of the test-piece. This relation deduced by the law of similarity shows that the test length should be proportional to the square root of the cross-section, and that fundamental law has been admitted also by the Conventions. The only difference is in respect to the value of the coefficient adopted.

While our formula

$$\Lambda^2 = 66\ 67\ \Omega$$

$$\text{or}\quad \Lambda = 8.16\ \sqrt{\Omega}$$

results in giving a diameter of 27.64 millimeters to a test-piece, having a test length of 200 millimeters, the formula of the Conventions

$$\Lambda = 11.3\ \sqrt{\Omega}$$

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* The original resolutions require that the actual length shall exceed the test length by 20 millimeters.—O. M. C.

leads to a smaller diameter for the same test length, for it gives in fact a diameter of 20 millimeters to a test-piece 200 millimeters long. In a general way this formula recommends itself on account of its great simplicity, inasmuch as the calculation of the linear dimensions is immediate; the useful or test length amounting always to ten times the diameter.

Our formula presents, on the other hand, the advantage of expressing the area by a simple number, for example, 600 square millimeters for a test-piece 200 millimeters in length, considering that it is better to seek simplicity in expressing the cross section rather than in indicating the diameter, because no matter what number expresses the diameter, the difficulty of measuring it is always the same, whereas it is only the section which intervenes in the calculations, and the adoption of a simpler number to express the section greatly facilitates such calculations

Notwithstanding the employment of the law of similarity, the two resolutions preserve well-defined normal types, to which they recommend that reference be made. These are four in number in the two cases.

Our standards have, respectively, test lengths of 70, 100, 141, and 200 millimeters; cross-sections of 75, 150, 300, and 600 square millimeters, and diameters of 9.77, 13.82, 19.55, and 27.64 millimeters. The standards of the Conventions give sections very closely resembling these, but their longitudinal dimensions are greater; they have lengths, respectively, of 100, 150, 200, and 250 millimeters for diameters of 10, 15, 20, and 25 millimeters.

Those standard types are adopted for steel and iron, as well as for copper and its alloys; for castings, however, the Conventions prescribe test pieces having a diameter of 25 millimeters, and a useful or test length of 200 millimeters.

The American Society prescribes four standards with diameters, respectively, of 0.4, 0.6, 0.8, and 1 inch, which equals 0.010, 0.015, 0.020, and 0.025 millimeter, but it preserves a constant useful or test length of 8 inches (0.2 meter), ignoring the differences which must occur in the measurement of total elongation by testing with a uniform length and a variable diameter.

The test length of 8 inches, as well as the various diameters given, have been chosen, moreover, for the purpose of approaching as nearly as possible the measures of the metric system, counting 8 inches as equal to 200 millimeters. This is expressly stated by the Society itself.

The law of similarity thus admitted, as has been shown, for cylindrical test-pieces, is extended by our Commission, with the same coefficient, to test-pieces of square cross-section, and even to pieces that are simply rectangular, observing carefully certain restrictions established with a view to facilitate manufacture, by establishing different series, in each one of which the width remains the same.

The Conventions also extend the formula expressing the law of similarity to test-pieces of simply rectangular cross section, but without introducing any definite restrictions. They recommend, however, that the section 30 by 10 shall be considered as the standard, even when the breadth and thickness may be chosen at pleasure.

When the thickness is given, as for plates, and when it does not exceed 24 millimeters, a width of 30 millimeters should be adopted.

Whenever the thickness exceeds 24 millimeters it should be considered as breadth, and a thickness of 10 millimeters should be given to the test-piece.

When the testing machines are not sufficiently powerful, the limit of 24 millimeters should be replaced by that of 16 or 17 millimeters.

The American Society permits on its part a width of 1.2 inches (0.030 meter) for rectangular test-pieces having a thickness of less than 1 inch (0.025 meter).

If the thickness reaches 1 inch the measure of 0.8 inch (0.02 meter) will be taken for the width.

In testing sheets and plates the crust produced in rolling should not be removed.

In testing sheets there should be taken two samples having the total section of the bar.

Besides the preceding rules just given, which are considered applicable only to rectangular test-pieces having a thickness of more than 5 millimeters, our Commission has adopted special dimensions for test-pieces having a thickness of less than that figure, considering that it is not necessary to be guided by the law of similarity, because that law is doubtless no longer applicable in such a case.

The useful or test length of those thin test-pieces has been fixed uniformly at 100 millimeters, without reference to the thickness or the nature of the metal to be tested.

CONDUCT OF TESTS.

Our resolutions recommend, as has been indicated, operating by progressive or gradual tension. This recommendation is also found in the resolutions of the Conventions, but the American Society permits interruption of the test, without relieving, however, the action of the strain, for the purpose of making certain important observations during the course of the test, such as those relating to the elastic limit (yield point).

In general, the American Society recommends the utmost care in placing the test-pieces, so that they may be directly in the axis of the machine, and to this end it advises that it should be referred carefully to two normal planes intersecting each other in line with this axis.

The Society also recommends placing test-pieces for tensile tests under a very slight initial strain (from 0.7 to 1.4 kilograms per square millimeter) before commencing observations, in order that the errors generally made at the beginning of a test may be avoided.

In regard to the rate of testing, our Commission has confined itself to giving some approximate directions, and it observes, to that end, that the duration of a test, which should be in a certain measure a function of the volume of the test-piece, should be comprised between one and six minutes for current tests on test-pieces of ordinary dimensions. This time may be reduced to thirty seconds for small test-pieces having a thickness of less than 5 millimeters. Care should be taken, especially with soft metals, to avoid heating the bars.

The foreign resolutions make no recommendations upon this subject. The Conventions, however, observe that in establishing the diagram of tensile test great importance should be attached to showing with what rapidity the diagram was traced.

CHAPTER II.—PRESSURE TESTS.

TESTS ON SHORT PIECES.

For determining the elastic limit our Commission advises the employment of cylindrical test-pieces having a diameter of 27.65 millimeters (600 square millimeters in cross-section) and 100 millimeters of useful or test length; but for the determination of the maximum resistance to compression or crushing the diameter of the standard test-pieces will be reduced to 19.56 millimeters (300 square millimeters of cross-section), and the useful length to 20 millimeters.

The regulations of the Conventions propose in testing castings the use of cubes of 25 millimeters a side, making them serve as samples for pressure tests. In another passage, however, they recommend a height of 30 millimeters.

They give no complementary information on the subject of that test, merely stating that Wachler adopted 25 millimeters as the standard dimension in his studies.

The American Society considers that pressure tests upon short test-pieces are of little interest, recommending, preferably, the adoption of pieces of a length of from 10 to 20 diameters.

However, when it is a question of determining the resistance to disaggregation, the use of cylinders 1 inch in diameter (0.025 meter) and 2 inches in height (0.050 meter) is proposed. Whenever the elastic resistance is to be determined the height will be increased to 10 or 20 inches (0.254 meter or 0.508 meter), always keeping the useful or test length at 8 inches, as in tensile tests.

TESTS ON LONG PIECES (FLAMBEMENT).

Our Commission insists especially upon the interest of making buckling tests, stating that for iron and steel the resistance determined by the tests thus made is in no way proportional to that determined by tensile tests, and in the existing state of science cannot be deduced from the results obtained by the usual tests.

The Commission declares that the tests can be made on riveted pieces or on bars cut up for this purpose, and it observes that to render the two tests comparable it is sufficient that the ratio of the length of the test-piece to the minimum radius of gyration of the section should have the same value. In tests upon test-pieces, the Commission proposes to give to that ratio values which are multiples of 5 or 10.

It recommends that those tests shall always be made under well-defined conditions, such as those by perfect hinging or complete clamping. The precautions to be observed in the first case are prescribed, but it is added that no satisfactory disposition for such testing by clamping is yet known.

The foreign resolutions give no particular instructions regarding pressure tests on long pieces. However, the American Society provides for tests upon pieces having a diameter of 1 inch and from 10 to 20 inches long for determining the elastic limit (yield point).

It requires that the process shall be the same as in tensile tests, dividing the useful or test length into small sections in such a manner that the loss in value sustained may be determined from its elements, and that the calculation of the modulus and the coefficient of elasticity shall be made under like conditions.

CHAPTER III.—TRANSVERSE TESTS.

TESTS ON TEST-PIECES.

CASTINGS.

Our Commission adopts for standard bars a section having a side of 40 millimeters, indicating that the total length should be determined in such a manner as to give a useful or test length of 150 or 500 millimeters according to the apparatus used (Monge or Joëssel balance).

The Conventions have adopted a prism 3 centimeters on a side, with a total length of 110 centimeters, giving a useful or test length of 100 centimeters. They recommend measuring the resistance to flexure up to the point of rupture and the corresponding work on three test-pieces. The faces of the pieces should be left in their rough condition.

Our Commission prescribes that the faces of the bars shall be shaped by a machine and the edges rounded by a file. It regulates finally the duration of the test, which should be comprised between one and two minutes.

The American Society requires for scientific tests that the effect of superficial quenching shall be avoided by using bars measuring at least 2 inches on a side (0.050 meter) or 2½ inches in diameter (0.063 meter). In current practical tests there will be used bars measuring only 1 inch (0.025 meter) on a side, taking the necessary precaution to throw aside surfaces which have been hardened or marked with blow holes.

STEEL PLATES FOR SPRINGS.

Our Commission fixes the length to be adopted for developed test-bars at 1 meter, the section to be used, however, being preserved without any modification.

The plate will be prepared under the same conditions as to quenching and annealing as the springs.

For testing it will be placed on two movable slides, the use of which is also recommended by the American Society.

The test will be continued without stopping or lessening the load and with a regular and continuous movement up to the limit fixed upon, in such manner that the duration of the whole test is comprised between two and five minutes.

The foreign recommendations contain no special remarks upon that subject.

The American Society recommends, however, in a general way, regarding transverse tests, that the sample should be placed firmly in a horizontal position to avoid supporting wedges, that the strain shall be brought to bear exactly in the middle and normal to the axis of the piece, and in a plane passing through the three strained points. It requires that the bars used shall be 1 inch (0.025 meter) on a side, have a length of 40 inches (1.016 meters), and that they shall be placed upon supports 36 inches apart (0.914 meter).

According to the resolutions of the Society the deviations should be measured from a fixed and invariable base. It is well to determine them at points situated at stated intervals from the middle of the bar in such a manner as to obtain certain elements of the curve of flexure over the whole extent of the length, and especially in the vicinity of the elastic limit (yield point).

Certain values of the permanent deviation may also be determined.

TESTS ON FINISHED OR WHOLE PIECES.

SPRINGS OF PARALLEL AND SPIRAL PLATES.

Our Commission recommends in transverse tests that springs be subjected to a less strain than that which corresponds to permanent deformation.

The American Society, on its part, proposes to apply the maximum working load, and to determine the deviation produced by that test. The test load will be obtained by proceeding by pressure or by shock, according to circumstances, but it will be applied only once.

RAILS AND FISH PLATES.

Our Commission recommends determining as nearly as possible the load corresponding to the proportional limit of elasticity in testing those pieces; it adds that the duration of the tests should be comprised between two and five minutes.

The foreign resolutions examine also the question of transverse tests by static pressure, requiring that they shall be considered from the two following points of view: First, there will be determined the elastic limit (the point where the set becomes permanent); second, there will be measured the flexibility under increasing loads, exceeding even the elastic limit.

The American Society states that it is hardly practicable to subject either rails or axles to a transverse test by static pressure.

CHAPTER IV.—FOLDING, BENDING, AND CURVING TESTS.

Our Commission proposes to adopt for those tests standard bars 40 millimeters wide and 250 millimeters long, observing that the length may be reduced to 150 millimeters for copper and its alloys. It recommends, besides, that those various tests shall be made by a machine so arranged as to produce a slow, progressive strain, and that in folding tests the initial fold shall be obtained with a radius of curvature differing as little as possible from that exacted for the limiting fold.

For mechanical folding the use of the hydraulic press or hammer is recommended.

Our Commission gives, besides, certain directions for folding done by a hand vise. It is necessary to observe here that this mode of testing is prohibited by the American Society.

In regard to bending tests, our Commission has not yet fixed upon any stated diameter for the mandrel.

For curving tests it proposes to adopt such machines as will permit the measurement at each instant of the developed strain and the corresponding deformation.

The Conventions recommend, as has been indicated, the use of slow-moving apparatus, acting either upon the middle or at the extremity of the test-bar, but they require especially bending around a mandrel for the hot and cold folding test of irons and steels of all kinds, fixing upon a diameter of 25 millimeters for mandrels to be adopted in the case of wrought or cast iron for bridges and of boiler plates more than 6 millimeters in thickness. The mandrel should not be removed during the test until the ends of the test-pieces have become parallel to each other, and the bending will be continued to the point of contact in the case of test-pieces of copper.

They add that the test-pieces employed should have a rectangular section, the width of which should be three times the thickness, and that the edges should be slightly rounded.

They observe, besides, that the angle-folding alone is not sufficient for judging of the degree of deformation of the test-piece, but that it is also necessary to take into account the radius of external curvature. They propose to make this measurement direct by means of templets, or to deduce it from the measure of the elongation upon the exterior face.

They require, finally, that the permanent committee shall search for the most convenient method of measuring deformations, and they also require that it shall look into folding tests made upon defective pieces.

The American Society also recommends the bending test around a mandrel, but it prescribes the use of mandrels of variable diameters, and it recommends giving them a diameter equal to twice the thickness of the bar to be tested.

It approves, finally, the use of a very simple apparatus which shall permit that test to be made rapidly. It fixes 1 inch (0.025 meter) as the standard width to be given test-pieces for folding tests.

CHAPTER V.—TORSION TESTS.

Our Commission confines itself to expressing the hope that experiments shall be continued with regard to the study of torsion.

The American Society has given certain instructions, previously indicated, with regard to the installation of apparatus to be used in those tests.

With regard to test-pieces, it recommends the use of cylindrical heads, prohibiting absolutely square-shaped heads. It gives a sketch of the position to be given the fastenings, and it demands that the distance between the head and the nearest point of reference shall not be less than one diameter.

It gives nothing concerning the determination of the useful or test length.

CHAPTER VI.—MIXED TESTS (SHEARING AND PUNCHING).

Our Commission has expressed the wish that the study of those tests may be continued, and it has proposed certain recommendations which may serve as a beginning for subsequent regulation.

The resolutions of the Conventions say nothing upon this subject; they recommend only that certain plates, like those of wrought iron for boilers, shall be submitted to the punching test, but they claim that the test is useless for plates of mild steel or ingot iron, which should never be punched.

The American Society remarks that in this test special care should be taken to determine the space to be reserved between the edge of the finished bar and the edge of the hole punched in the interior of the section, in order that cracks may not be formed.

This question is being studied by numerous experts both in France and in America.

SECOND CLASS.—METHODS OF TESTING BY ABRUPT ACTION.

Our Commission, in common with the foreign resolutions, indicates the particular interest to be found in shock tests, for they give information which gradual action cannot furnish. It recommends that study concerning tensile tests by shock and the use of explosives may be continued.

CHAPTER I.—TRANSVERSE TESTS BY SHOCK.

Our conclusions relate especially to tests on test-pieces, as has been shown above. They fix the dimensions to be given to test the bars, according to the nature of the metal tested, regulating under the same conditions the weight of the hammer, the form of the striking face, and that of the edges of the supports.

They recommend, besides, a continuance of theoretical research, to ascertain the respective effects of the two elements which are the component parts of the energy of shock, namely, the weight of the hammer and the height of fall. They require that for each metal there shall be determined the height of fall above which the fragility increases rapidly, that there shall be studied the effect of constantly increasing heights of fall in ordinary transverse tests made on test-pieces resting upon two supports, and finally that there shall be studied tests made by bringing the shock to bear upon the free end of test-pieces clamped at one end only.

Those different subjects are not examined in the foreign resolutions, which give special attention to tests upon whole pieces, and determined, as has been indicated, the weight of the hammer and the height of fall to be used.

In tests upon finished pieces the resolutions of the Conventions recommend the use of bearing blocks or caps of such form that the upper surface of the piece shall be perfectly horizontal, the face of the hammer being always perfectly smooth and plane. Those pieces should be as light as possible.

Our Commission appears to think, however, that the use of those caps may be dispensed with when it is a question of testing pieces before sustaining in service blows which would be of such a character as to alter them.

In a paper on shock tests, presented to the American Society at its meeting of August, 1894, in Brooklyn, by Mr. Mansfield Merriman, Vice-President of the Society, the author recommends the disuse of those caps; he proposes to give the hammer a large striking surface to avoid loss of energy by heat, and to take account of the rebound of the hammer.

The Conventions claim, on the other hand, that the data derived from tests thus far made are not sufficiently conclusive to admit of giving any fixed form for either the supports or the pieces destined to receive the shock.

In observations on the results, they declare that it is sufficient to determine the curvature deflection to within about 1 millimeter, when it is measured on a cord of from 1 to 1.5 meters in length.

In a general way they recommend, as has our Commission, the taking of careful notes regarding all the peculiarities of the test, stating, for example, whether there had been any interruption during the test, whether the pieces had been turned over, etc.

CHAPTER II.—SUPERFICIAL PENETRATION TESTS BY SHOCK.

That mode of testing, minutely studied by our Commission, has not been examined in the foreign resolutions.

CHAPTER III.—PERFORATION TESTS BY SHOCK.

Our Commission has only been able to express a desire that new experiments should be made for the purpose of solving the various questions which have been brought up by that method of test. The study of that method of test has not, as yet, been broached by the Conventions or by the American Society.

THIRD CLASS.—STUDY OF HARDNESS AND FRAGILITY.

CHAPTER I.—PROPOSED DEFINITIONS AND METHODS OF MEASURING.

Our Commission has reserved the study of that subject for a future session.

CHAPTER II.—TESTS OF HARDNESS BY SCRATCHING AND BY RESISTANCE TO WEAR AND TEAR.

Our Commission has expressed the hope that those two subjects might be the object of complemental studies.

The Conventions have expressed a like hope in reference to the wear and tear of rails and tires, requiring that those tests shall be made under conditions as nearly like those of practice as possible.

The American Society declares that it is impossible to present any recommendations upon that subject; however, it points out that for rails it is proper to make tests upon curved pieces, and to take into consideration the action of shock, of rapid rolling, and of variations in temperature and humidity.

CHAPTER III.—FOLDING TESTS AFTER COLD HARDENING BY PUNCHING, OR AFTER CUTTING.

The Conventions have charged the permanent committee with searching for the causes of irregularities in ingot iron shown by unexpected breakages, notwithstanding tests upon the broken pieces had given satisfactory results.

Our Commission considers that folding tests made after cold hardening (*écrouissage*) or cutting should show those irregularities, and it has given in this respect certain practical rules which may in some measure bring out the information desired by the Conventions.

FOURTH CLASS.—TESTS OF MANUFACTURE.

CHAPTER I.—COLD WORKING TESTS.

The enlarging upon the mandrel, the heating, the flattening, and crushing tests, all studied in our resolutions, are not mentioned by the foreign resolutions.

CHAPTER II.—HOT WORKING TESTS OF IRONS AND STEELS.

TESTS BY BENDING AND FOLDING.

Our Commission points out certain tests to be made on plates, angle iron, and facing iron; for bars cut from plates the same dimensions are assumed as for cold folding.

It points out that all these tests should be made at the same heat.

The Conventions recommend that certain kinds of metals, such as ingot or wrought iron for bridges, and plates of ingot iron or mild steel for boilers, shall be subjected to the hot folding test. For the latter a test will also be made after quenching. The hot test is made around a mandrel under the same conditions as in cold bending.

TESTS BY STAMPING, BENDING INTO HOOKS, BORING, PRESSING, FORGING, FLATTENING, AND WELDING.

The greater part of those tests are not mentioned in the foreign resolutions, except those by flattening and welding.

The Conventions recommend those two modes of test for different kinds of metals without trying to establish any definite rules.

They declare that it is difficult to generalize from tests by welding, since much depends upon the skillfulness of the operator, and they have determined to require a sub-committee to study the utility of the various hot tests.

The American Society requires recourse to be had to the flattening test for testing riveted bars, and it states, as does our Commission, that the amount of spreading out obtained before the appearance of fissures furnishes one measure of the quality of the metal.

It insists strongly on the welding test, stating that such a test has a special importance in the United States, inasmuch as welded pieces are frequently used there.

It gives the precautions to be observed in welding, which should be done at one temperature, a white heat, and it requires that after the operation the test-piece shall be submitted to a tensile test.

Another sample should be submitted to a folding test after a groove has been made of a depth equal to that of the weld.

The American Society demands that the welded bars shall be allowed to cool without being wet.

It does not prescribe the boring or piercing test after welding recommended by our Commission.

FIFTH CLASS.—SPECIAL TESTS ON CERTAIN FINISHED PIECES.

The foreign resolutions insist strongly upon the great interest that there will be in being able to make tests upon the finished pieces themselves; they require that in setting up testing machines the possibility of making tests on finished pieces shall be kept in mind. They add that the shock test is generally the most important, and for certain pieces in frequent use on railroads they recommend or prescribe certain special tests.

Our Commission, however, does not feel at liberty to formulate any such resolutions, and in making its studies of tests on finished pieces it confines itself to pointing out the method of executing the tests without indicating that any one may be superior to the others.

CHAPTER I.—TESTS ON WIRE.

Our Commission has studied the principal tests that may be made on wire—*i. e.*, tensile, folding, winding, and torsion.

The Conventions require upon this subject only that the torsion test shall be made by means of suitable machines, and that the folding test shall be made by machinery bending the piece alternately in two opposite directions around a mandrel 5 millimeters in diameter.

The American Society reproduces those conclusions, requiring, however, that the diameter of the mandrel shall be equal to that of the wire.

The analogous test studied by our Commission is that of winding or wrapping. It requires that the diameter of the roller or spool shall vary according to the destined use of the thread, but requires that it shall be always a multiple of the diameter of the wire.

CHAPTER II.—TESTS ON WIRE, ROPE.

Our Commission prescribes the rules to be followed in tests for tension and flexibility. The Conventions and the American Society require that a tensile and a shock test shall be made in the longitudinal direction without giving any further details on that subject. Our Commission expresses the hope that the study of tensile tests by shock may be continued, as well as the folding or winding tests, in order to furnish information as to flexibility.

The Conventions add that the folding test is of value only when continued for a given length of time.

CHAPTER III.—TESTS ON CHAINS.

Our Commission proposes submitting chains to a tensile test made at first under a moderate load, then carried to rupture, and it gives some instructions relating to the execution of that test. For the test under a moderate strain it proposes adopting a strain double that to be met with in actual service.

The American Society requires only that the chain shall be subjected to the service strain, and that the elastic and permanent elongation shall be measured as well as the change in the form of the links.

CHAPTER IV.—TESTS ON RIVETS.

As a special test on bars for rivets, the American Society presents only the hot flattening test.

Our Commission gives two principal tests; one to separate the two riveted bands or bars by means of a chisel with a given bevel driven by blows of a hammer, and the other to subject those bars to a sort of shearing test.

CHAPTER V.—TESTS ON PIPES AND TUBES.

The foreign resolutions give no special information in regard to the manufacture test to be made on pipes or tubes.

CHAPTER VI.—TESTS BY HYDRAULIC PRESSURE.

For tests of steam boilers the American Society recommends the adoption of the method used by the Hartford Inspection Company, which is already in general use in the United States.

Our Commission, without prescribing the methods of test required in France, points out the precautions to be observed and the verifications to be made in testing boilers.

For testing cylinders and pipes the American Society proposes the application of a pressure equal to the maximum working load. It requires, besides, that the dilation of pipes under that load shall be observed, as well as the permanent dilation, if any be produced, and to mention whether the pipe leaks.

In conclusion, our Commission recalls the fact that hydraulic pressure has been used recently to acquire desired data relating to the elastic deformation of metals; and it expresses the hope that those studies may be extended to plates.

PARIS, *March 15th, 1895.* L. BACLÉ.

OBITUARY.

GEORGE W. G. FERRIS, widely known as the inventor of the Ferris wheel, which was one of the leading features of the World's Fair at Chicago, died on November 22d, at Mercy Hospital, Pittsburg, Pa., from typhoid fever. He was born at Galesburg, Ill., but passed his early life on the Pacific coast, and was educated at San Francisco. In 1876 he entered the Rensselaer Polytechnic Institute, at Troy, N. Y., from which he graduated. Subsequently he entered the employ of the Louisville Bridge Company, at Louisville, Ky. Among other work which came under his direction in connection with this company was the structural work for the Louisville & Nashville Railroad bridge, at Henderson, Ky. After the completion of this work he organized the firm of G. W. G. Ferris & Co., in Pittsburg. In 1893 Mr. Ferris constructed the wheel which brought him a reputation throughout the world as an original engineering genius. Mr. Ferris had sold out his interest in the wheel some time before his death.

THE REFRACTIVE INDEX OF LUBRICATING OILS.

By G. W. Bissell, Ames, Iowa.

THE object of this paper is to present the results of some experiments made by the writer to discover the relation, if any, which exists between the index of refraction of an oil and some of its other properties, such as viscosity and specific gravity. The writer was led to make the experiments because the test for index of refraction is very readily, quickly, and accurately made.

The first series of tests was made by determining the viscosity, specific gravity, and refractive index of each of several mineral oils, all being the product of one refinery.

The results appear in the following table:

Name of Oil.	Refractive Index at 68° F.	Viscosity at 71° F.	Specific Gravity.
Water White Kerosene,	1.4434	10.6	——
Sewing Machine,	1.4695	14.2	——
Filtered Spindle,	1.4909	19.0	0.888
A. M. Spindle,	1.4942	19.6	.898
Arctic Engine,	1.4812	22.6	.873
Dynamo,	1.4825	22.9	.877
Arctic Machine,	1.4839	24.6	.874
Light Machine,	1.4885	27.6	.883
Red M. Engine,	1.4809	47.8	.877
Locomotive Engine,	1.4894	84.5	.970
Heavy Marine Engine,	1.4822	108.4	.894
Dark Marine Engine,	1.4869	120.0	.893
600 W. Cylinder,	1.4886	——	——

The viscosities are in seconds, and were obtained with a P. R. R. 100 cc. viscosity pipette.

The indices of refraction were obtained with an Abbé Refractometer, which actually measures the angle of total reflection, but is graduated to give refractive indices direct to four decimal places.

The second series of tests were made to determine the difference in refractive indices of mixtures of a clean machine-oil taken from the tank with varying proportions of the same oil after it had been run through bearings and was in need of filtering.

The following table shows the results:

Percentage of Clean Oil.	Percentage of Dirty Oil.	Refractive Index.	Temperature.
0	100	1.4816	69
10	90	1.4814	"
20	80	1.4815	"
30	70	1.4819	"
40	60	1.4804	"
50	50	1.4812	70
60	40	1.4814	71
70	30	1.4812	"
80	20	1.4811	"
90	10	1.4809	"
100	0	1.4816	69

The conclusions derivable from the above data are that there is no relation for the oils tested between the refractive index and either the viscosity for the specific gravity, and that dirty or cloudy oil has the same refractive index as unused oil of the same grade. This latter conclusion is in accordance with other investigations made in Germany, which showed that cloudiness of a liquid does not change its refractive power.

[Translation from article in *Stahl und Eisen*, January 1st, 1896.]

INVESTIGATIONS REGARDING THE INFLUENCE OF COLD UPON THE STRENGTH OF IRON AND STEEL.

By Professor M. Rudeloff.

A COMMISSION received from the Imperial Dock-yard at Wilhelmshafen by the Charlottenburg Experimental Station, presented the opportunity of making thorough investigations regarding the influence of cold as low as 80° C. upon the strength of various kinds of iron and steel. In view of the importance of this question, and in order to make the results of these investigations accessible to a wider circle of readers, a concise compilation of them is here given, while, regarding the details of the examination and the results obtained thereby, the reader is referred to the article on the same subject in *Mittheilungen aus den Königlichen technischen Versuchsanstalten*, 1895. Heft 5.

The investigations embraced tensile, bending, and riveting tests at the ordinary temperature of a room, as well as at 20° C., and at 80° C., three parallel experiments being always made.

In making the tests the following materials were employed:

1. Soft rivet iron (weld iron), round rods 25.5 millimeters in diameter.
2. Siemens-Martin ingot iron, angle of 100x100x14 millimeters.
3. Thomas steel from "Roth Erde," the same as No. 2.
4. Rolled weld iron, angle of 100x65x9 millimeters.
5. Spring steel, round rods 25 millimeters in diameter.
6. Cast steel, same as No. 5.
7. Wrought weld iron (tilted or hammered iron), same as No. 5.

For the tensile experiments small cylindrical rods were prepared from the round rods, and flat pieces from the angles. The dimensions adopted for all test-pieces were 80 millimeters cross-section and 100 millimeters testing length, so that all the materials could be directly placed in comparison with one another. The tests were executed with a 50-ton Pohlmeyer machine under a steadily increasing load with a working velocity as equal as possible.

For the riveting tests cylindrical pieces of a length equal to the diameter which, according to the original thickness of the material, amounted to from 8 to 10 millimeters, were used. Each piece received 10 blows of equal specific effect (*a*) which, for the materials Nos. 1 to 4 and No. 7 with a tensile strength of less than 50 kilogrammes per square millimeter, was adopted equal to 5 mkg. per ccm., and for the materials Nos. 5 and 6, with a tensile strength of over 50 kilogrammes per square millimeter, equal to 20 mkg. per ccm.

For the bending tests pieces 150 millimeters long were used. The test-pieces from the round rods Nos. 6 and 7 were not subjected to further manipulation, while for the purpose of facilitating bending the round rods Nos. 5 and 6 were turned down to 15 mm., and the test-pieces from the angles were cut 30 mm. in width and rounded off on the edges. Bending was induced in a screw press under a spindle 25 mm. in diameter to about 90°, and then continued by means of a steadily increasing load upon the leg ends.

For the experiments at —20° C., the chilling of the test-pieces was effected in a freezing mixture of ice and salt, and for the experiments at —80° C., in solid carbonic acid. In the tensile tests the pieces re-

TABLE I.

COMPARISON OF THE MEAN VALUES FROM TENSILE EXPERIMENTS.

MATERIALS.	Experimental Temperature °C.	Observation Values.				σ_S / σ_B	Proportional Figures.			
		Strains in Kilos Per Square Millimeter on the		Elongation by Rupture Measured in Per Cent. for			Strains in Kilos Per Square Millimeter on the		Elongation by Rupture Measured in Per Cent. for	
		Limit of Extensibility σS.	Limit of Rupture σB.	Each 30 Millimeters from Rupture.	90 Millimeters.		Limit of Extensibility σS.	Limit of Rupture σB.	Each 30 Millimeters from Rupture.	90 Millimeters.
1. Soft Rivet Iron (weld iron) marked "N,"	+ 18	28.7	39.7	30.2	27.7	0.72	100	100	100	100
	— 20	29.2	41.7	29.0	26.2	0.70	101.7	105.0	96.0	94.6
	— 80	30.4	42.7	26.6	23.8	0.71	105.9	107.5	88.1	85.9
2. Rolled Steel for ship construction (Siemens-Martin ingot iron) marked "Krupp,"	+ 18	24.0	40.4	39.5	32.8	0.59	100	100	100	100
	— 20	24.7	43.6	38.0	33.3	0.57	102.9	107.9	96.2	98.5
	— 80	29.7	45.2	—	(23.4)	0.66	123.8	111.9	—	(70.3)
3. Rolled Steel for ship construction (Thomas Steel from "Rothe Erde,") marked "Rothe Erde,"	+ 18	28.7	43.4	35.3	30.2	0.66	100	100	100	100
	— 20	30.4	45.5	33.8	29.5	0.67	105.9	104.8	95.8	97.7
	— 80	32.0	46.2	(31.9)	(26.2)	0.69	111.5	106.5	(90.4)	(86.8)
4. Rolled Weld Iron for building construction, marked "W,"	+ 18	30.9	40.2	(23.8)	21.3	0.77	100	100	100	100
	— 20	31.6	41.6	23.5	21.7	0.76	102.3	103.5	(98.7)	101.9
	— 80	31.9	43.2	—	20.2	0.74	103.2	107.5	—	94.8
5. Spring Steel, marked "F S,"	+ 18	38.7	77.2	17.7	16.0	0.50	100	100	100	100
	— 20	40.2	84.2	15.7	14.0	0.48	103.9	109.1	88.7	87.5
	— 80	44.4	84.4	12.8	10.9	0.53	114.7	109.3	(72.3)	68.1
6. Cast-Steel (crucible steel), marked "T S,"	+ 18	45.6	79.3	20.1	17.1	0.58	100	100	100	100
	— 20	45.7	81.6	20.0	16.8	0.56	100.2	102.9	99.5	98.2
	— 80	48.7	84.1	17.6	13.9	0.58	106.8	106.1	87.6	81.3
7. Wrought Weld Iron (tilted or hammered iron), marked "H,"	+ 18	27.3	37.1	26.3	21.3	0.74	100	100	100	100
	— 20	27.6	37.9	26.1	21.9	0.73	101.1	102.2	99.2	102.8
	— 80	32.1	40.3	(27.8)	23.3	0.80	117.6	108.6	105.7	109.4

mained in the cold baths during the entire experiment, while in the riveting and bending tests the pieces were taken from the baths for examination, but returned to them for 15 minutes to be chilled again, the pieces for the riveting tests being thus returned after each blow.

a. The mean values for the results of the tensile experiments are compiled in Table I, and graphically represented in Figs. 1 to 3. They admit of the following general deductions:

1. By cooling, the strain on the limit of extensibility as well as the breaking strain are increased.

2. With an equal fall in temperature the change in the limit of extensibility by reason of cooling to —20° C., is, generally speaking, slight as compared with that between —20° and —80° C., while the breaking strain is proportionally more influenced by slight cooling (to —20° C.) than by stronger cooling (to —80° C.).

3. Elongation by rupture (Fig. 3) decreases with increasing cold, and increases only with wrought weld iron (tilted or hammered iron). This influence is partially proportional to the fall in temperature and partially it first becomes especially pronounced between —20° and —80° C.

A comparison of the different varieties of iron shows that in the breaking experiment the Siemens-Martin ingot iron resisted least the influence of cooling to —80° C., the changes for the limit of extensibility amounting to + 23.8 %, for the breaking strain to + 11.9 %, and for the elongation to 90 mm. length to about —30 %*. Next to the Siemens-Martin ingot iron comes the spring steel (+ 14.7, + 9.3, and —32 %) †; then follow hammered iron (+ 17.6, + 8.6, and + 9.4); Thomas steel (+ 11.5, + 6.5, and —13.2); cast steel (+ 6.8, + 6.1, and —18.7 %); soft rivet iron (+ 5.9, + 7.5, and —14.1 %); and rolled weld iron (+ 3.2, + 7.5, and —5.2 %).

An interesting phenomenon in the rupturing experiments deserves special mention—namely, that, with increasing cold down to —80° C., all the varieties of iron and steel exhibited an increase in the flowing power (Fliessvermögen) under the load at the limit of extensibility, which, with a constant velocity of the rupturing machine, is given by the length of the extension *l* in the traced line, Fig. 4.

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* This value is doubtful, because of the three test-pieces tested at —80° C., two broke outside of the division, and the rupture of the third test-piece took place in the last division mark.

† These and the succeeding values are given in the same succession as for Siemens-Martin iron.

The separate values for the length of *l* were determined by the lines traced by the machine during the experiment, and are compiled in Table II. They show that the increase in the flowing power (Fliessvermögen) under the load at the limit of extensibility was a general one, and showed itself even in materials Nos. 4 and 5—rolled weld iron and spring steel—which did not possess it at the ordinary temperature of a room.

TABLE II.

LENGTH OF THE HORIZONTAL PORTION *l* OF THE TRACED LINES ON THE LIMIT OF EXTENSIBILITY.

MATERIAL.	1		2		3		4		5		6		7	
Experimental Temperature. °C.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.
+ 18 . .	1	2.5	10	1.2	19	1.2	28	0	37	0	46	0.2	55	1.0
	4	2.0	13	—	22	1.4	31	0	40	0	49	0.1	58	1.5
	Mean	2.3	Mean	(1.2)	Mean	1.3	Mean	0	Mean	0	Mean	0.2	Mean	1.3
— 20 . .	2	2.8	11	2.2	20	3.2	29	1.0	38	0.3	47	0.2	56	1.0
	5	3.5	14	2.8	23	4.0	32	2.5	41	0.2	50	0.9	59	1.0
	8	3.1	17	1.8	26	—	35	2.0	44	0.2	53	1.0	62	1.5
	Mean	3.1	Mean	2.3	Mean	3.6	Mean	1.8	Mean	0.2	Mean	0.7	Mean	1.2
— 80 . .	3	5.2	12	3.0	21	5.0	30	—	39	0.2	48	1.0	57	5.0
	6	4.2	15	3.2	24	5.2	33	3.6	42	1.0	51	1.2	60	(4.0)
	9	5.0	18	—	27	5.3	36	2.0	45	0	54	1.0	63	(9.0)
	Mean	4.8	Mean	(3.1)	Mean	5.2	Mean	2.8	Mean	0.4	Mean	1.1	Mean	6.0

This observation enters into close connection with that made by Charpy, according to which the flowing power (Fliessvermögen), while existing distinctly at the ordinary temperature of a room, gradually disappears with increased heating.

b. In view of the method used in making the experiments, *the results of the riveting tests* can be best reviewed by considering the decrease in height the test-pieces suffered after receiving blows of equal specific effect at the three different degrees of temperature. This comparison may be carried out for blows of an effect of 10, 20, 30, and 40 mkg. per ccm. For this purpose lines were constructed from the separate observation values, the repetition of which, for the sake of brevity, is here omitted by laying down the effects of the blows as abscisses and the decreases in height belonging thereto as ordinates, and from these lines the decreases in height for the effects of the four blows mentioned above were taken. The values obtained thereby are compiled in Table III, together with figures giving the proportion of decrease in height at lower degrees of temperature to that at the ordinary temperature of a room.

TABLE III.

INFLUENCE OF COOLING UPON THE DECREASE IN HEIGHT OF THE RIVETING TEST-PIECES BY BLOWS OF EQUAL SPECIFIC EFFECT.

MATERIALS.	Testing Temperature, °C.	Decrease in Height by the Effect of the Blows, taken from the Constructed Lines; in mkg. per ccm.				Proportion of the Decrease in Height at Lower Degrees of Temperature by the Effect of Blows to that at the Ordinary Temperature of a Room, the Latter Effect Placed = 100 in mkg. per ccm.				
		10	20	30	40	10	20	30	40	Mean.
1. Soft Rivet Iron (weld iron), mark'd "N,"	+ 18	13.2	21.5	28.1	33.2	100	100	100	100	100
	— 20	12.4	20.4	26.2	31.0	94	95	93	93	94
	— 80	9.5	16.6	22.0	27.0	72	77	78	81	77
2. Rolled Steel for ship construction (Siemens-Martin ingot iron), ...	+ 18	12.8	21.5	28.3	33.3	100	100	100	100	100
	— 20	12.8	21.5	27.0	32.0	100	100	95	96	98
	— 80	10.0	17.0	22.5	26.7	78	79	79	80	79
3. Same as above, Thomas Steel from "Rothe Erde," . .	+ 18	13.5	21.4	27.5	32.4	100	100	100	100	100
	— 20	12.0	20.0	25.8	30.7	89	94	94	95	93
	— 80	10.5	17.9	23.1	27.8	78	84	84	86	83
4. Rolled Weld Iron for building construction, . . .	+ 18	15.3	24.2	32.3	—	100	100	100	100	100
	— 20	13.0	21.4	27.5	—	85	88	85	—	(86)
	— 80	12.2	21.0	27.6	—	80	87	85	—	(84)
5. Spring Steel,	+ 18	7.8	14.7	20.2	25.0	100	100	100	100	100
	— 20	7.0	13.5	18.8	23.5	90	92	93	94	92
	— 80	7.1	12.0	17.2	22.0	78	82	85	88	83
6. Cast Steel, .	+ 18	8.3	15.5	21.5	26.5	100	100	100	100	100
	— 20	8.3	15.5	21.0	26.0	100	100	98	98	99
	— 80	6.0	12.0	17.8	23.3	72	77	83	88	80
7. Wrought Weld Iron (tilted or hammered iron), . . .	+ 18	13.8	22.8	29.7	35.1	100	100	100	100	100
	— 20	13.5	21.6	27.8	—	98	95	94	—	(96)
	— 80	12.2	19.5	24.5	28.9	88	86	83	82	85

From the mean values for these proportional figures it follows:

1. That the more the materials were cooled the less their shape was altered under blows of equal effect. Hence, by the influence of cold the capacity of the matertal for having its shape altered by riveting had suffered in a like manner as its power of extension in the rupturing experiment, though the influence upon the riveting capacity did not run entirely parallel with that upon the extensibility.

2. The magnitude in the loss of riveting power amounts at —20° C. up to 8 per cent., and at —80° C. up to 23 per cent.

3. By arranging the materials examined in accordance with the increasing influence of cold the following series is obtained: Hammered iron, rolled weld iron, Thomas steel, spring steel, cast steel, Siemens-Martin iron, and soft riveting iron.

c. The bending tests judged by the magnitude of the bend $Bg = 50 \frac{\delta}{\sigma}$, if δ equals the thickness or diameter of the test-piece and σ the diameter of the curve, and by the bending angle *w*, show:

1. That, generally speaking, cooling to —20° C. exerted but little influence upon the flexibility of the varieties of iron examined.

2. The flexibility of the test-pieces of soft rivet iron and rolled weld iron was not seriously affected by cooling to —80° C., but that of all the other materials suffered by reason of the lower temperature.

3. The greatest effect was produced on cast steel and spring steel; then follow Siemens-Martin ingot iron and Thomas steel with about the same effect, while the three varieties of weld iron showed the greatest resisting power. It must, however, be noticed that, notwithstanding the perceptible influence of cold, the Siemens-Martin iron and Thomas steel showed throughout greater flexibility at —80° C. than the rolled and wrought weld irons, and in this respect were not surpassed by the soft rivet iron (weld iron).

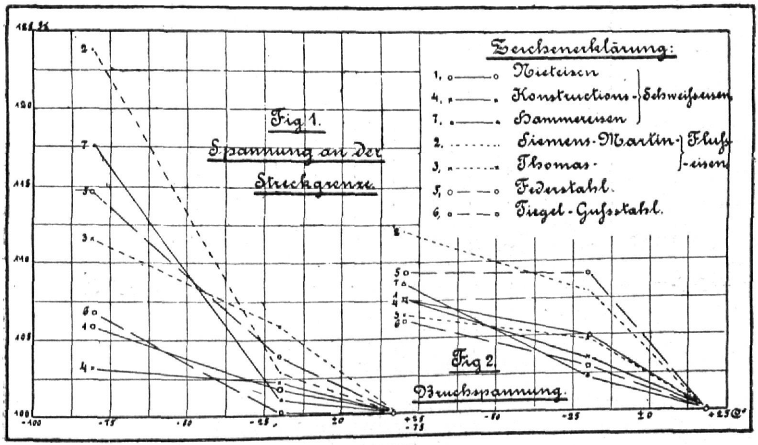

Fig. 1.—Strain on the limit of extensibility.
Fig. 2.—Breaking strain.

Explanation of the Figures.

1. o——o. Rivet iron.
4. x——x. Structural weld iron.
7. x——x. Hammered iron.
2. . . . Siemens-Martin, } ingot iron
3. x . . . x. Thomas, } ingot iron
5. o— —o. Spring steel.
6. o— —o. Crucible cast-steel.

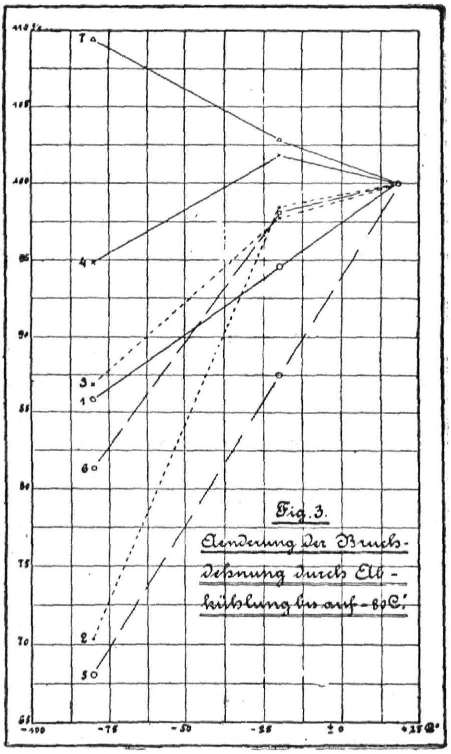

Fig. 3.—Alteration in the elongation by fracture by cooling to —80° C.

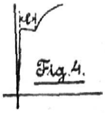

Fig. 4.

EFFECT OF AN ADDITION OF GYPSUM TO PORTLAND CEMENT.

F. SCHOTT has observed by the prisms in the Bauschinger apparatus the changes in volume of cements of different composition, and has compiled the results in the following table:

Hardening Time.	Extension per 100 Meters Length in Millimeters.							
	$2CaOSiO_2$.	100 Parts $2CaOSiO_2$ + 63 Parts Gypsum.	Kaolin Cement containing 12.53% Al_2O_3.	100 Parts Kaolin Cement + 63 Parts Gypsum.	Iron Cement containing 12.19% Fe_2O_3.	100 Parts Iron Cement + 38.7 Parts Gypsum.	$2CaOAl_2O_2$.	1 Part $2CaOAl_2O_2$ + 1 Part Gypsum.
7 days.	0	0	+ 30	Swells very much.	+10	+ 50	+190	+ 285
28 "	0	0	+120		+35	+210	+605	+ 785
90 "	— 5	0	+310		+35	+300	+705	+1240
180 "	— 7	—15	+540		+20	+385	+775	Swells very much.
270 "	—15	—20	+575		+15	+495	+880	
360 "	—20	—30	+600		+15	+690	+920	
1¼ years.	—40	—45	+610		+15	+886	+940	
1½ "	—60	—50	+630		—	—	—	

The greatest constancy in volume is exhibited by the cement containing only lime and silica, 100 parts of such cement mixed with 63 parts gypsum showing no extension, even after 1½ years, but a slight reduction in volume. The cement prepared from kaolin which, besides silica, contains 12.53 per cent. alumina, shows an essentially different behavior. Even without the addition of gypsum it exhibits strong extension, and mixed with 63 parts gypsum ($CaSO_4 + 2aq$) to 100 parts of cement it swells very much. The gypsum was measured to correspond with the 12.53 per cent. alumina, present by reason of the double combination of gypsum with calcium aluminate, $Al_2O_3,3CaO + CaSO_4$, assumed by Michaelis. While iron cement by itself behaves like good Portland cement, when mixed with gypsum it shows progressive strong extension, so that chemical actions similar to those between gypsum and calcium aluminate also take place between gypsum and calcium ferrate. The combination, $2CaOAl_2O_3$, shows from the start strong extension, which is still further increased by an addition of gypsum. To obtain a clear insight into the chemical processes upon which this phenomenon is based, the combination, $2CaOAl_2O_3$, was scorified and mixtures of it with 1, 2, and 3 equivalents of hydrous gypsum prepared. These mixtures were reduced to fine powder in an agate dish and 2 grammes of each brought into test-tubes previously weighed. Fifty c. cm. of water were then poured over the contents of the test-tubes to test their capacity for absorbing water. While 100 parts of the combination, $Al_2O_3 2CaO$, by hardening in water and forming the hydrate with 5 equivalents of water, absorb 41.92 parts of water, 100 parts of $Al_2O_3 2CaO$ in the presence of 2 equivalents of gypsum and the formation of the double combination with 18 equivalents of water reabsorb 118.38 parts of water, which explains the swelling.

STRENGTH OF CEMENT MORTARS AFTER HARDENING FOR SOME TIME IN THE OPEN AIR.

As a contribution to the hardening of cement mortar in the air by the action of carbonic acid, R. Dyckerhoff communicates the following results of his observations on mortar with 1 to 10 parts sand, made from cement which by the normal test showed a tensile strength of 23.6 kilogrammes and a compressive strength of 232 kilogrammes. The mortars were allowed to harden for one week in water, and were then exposed to the weather in the open air:

Mortar Mixture in Parts by Weight.	Residue in per cent.		Tensile Strength in Kilos for 1 Square Centimeter.								
	5000 Mesh Sieve.	900 Mesh Sieve.	1 Week.	4 Weeks.	13 Weeks.	26 Weeks.	1 Year.	2 Years.	3 Years.	4 Years.	5 Years.
1 cement : 1 sand,	22.3	3.0	25.5	27.4	41.4	41.9	45.5	62.3	61.5	63.3	69.1
1 " : 2 "	. .	. .	22.2	26.5	38.3	39.1	42.4	55.2	58.1	50.3	6.43
1 " : 3 "	. .	. .	18.6	23.4	34.5	35.4	36.6	50.9	46.2	56.3	5.79
1 " : 6 " + ½ calcium hydrate,	. .	. .	10.9	18.1	22.8	28.0	32.2	42.3	41.3	43.5	51.0
1 " : 8 " + ¾ " "	. .	. .	7.1	13.7	19.7	24.8	28.5	37.9	35.0	39.2	44.5
1 " : 10 " + 1 " "	. .	. .	5.4	11.6	17.0	21.3	23.4	34.4	31.2	36.0	36.9

The lime used for the experiments was hydraulic lime from Beckum, and the sand, Rhine sand sifted through a 5-millimetre mesh sieve.—*Chemisch technisches Repertorium.*

Bicycle Frame Tests—Luminum versus Steel Tube.

SUMMARY OF TESTS.

SERIES A. STATIC LOAD ON CRANK HANGER.

Luminum Frames, average crippling strength, . . . 2,775 pounds
“ “ “ ultimate “ . . . 3,623 “
Stearns “ “ crippling “ . . . 2,925 “
“ “ “ ultimate “ . . . 4,172 “
“ “ show 5½ per cent. higher crippling strength.
“ “ “ 15 “ “ ultimate “

SERIES B. STATIC LOAD ON SEAT POST

Luminum Frames, average crippling strength, . . . 4,219 pounds
“ “ “ ultimate “ . . . 4,344 “
Stearns “ “ crippling “ . . . 4,275 “
“ “ “ ultimate “ . . . 5,438 “
“ “ show 1½ per cent. higher crippling strength.
“ “ “ 25 “ “ ultimate “

SERIES C. STATIC LOAD IN LINE OF SPROCKETS.

Luminum Frames, average ultimate strength, . . . 1,750 pounds
Stearns “ “ “ “ . . . 2,600 “
“ “ show 48½ per cent. higher ultimate strength.

SERIES D. STATIC LOAD ON PEDAL ON ONE SIDE.

Luminum Frames, average crippling strength, . . . 300 pounds
“ “ “ ultimate “ . . . 1,268 “
Stearns “ “ crippling “ . . . 845 “
“ “ “ ultimate “ . . . 1,250 “
“ “ show 181½ per cent. higher crippling strength.
Luminum “ “ 1½ “ “ ultimate “

SERIES E. IMPACT ON SEAT POST.

Luminum Frames, average crippling strength, . 2,575 inch-pounds
“ “ “ ultimate “ . 4,055 “
Stearns “ “ crippling “ 13,300 “
“ “ “ ultimate “ 15,900 “
“ “ show 416 per cent. higher crippling strength.
“ “ “ 202 “ “ ultimate “

SERIES F. IMPACT ON CRANK HANGER.

Luminum Frames, average crippling strength, . 6,573 inch-pounds
“ “ “ ultimate “ . 6,820 “
Stearns “ “ crippling “ . 8,678 “
“ “ “ ultimate “ . 9,857 “
“ “ show 32 per cent. higher crippling strength.
“ “ “ 44½ “ “ ultimate “

SERIES G. HORIZONTAL IMPACT ON FRONT FORK.

Luminum Frames, average crippling strength, . 1,273 inch-pounds
“ “ “ ultimate “ . 1,575 “
Stearns “ “ crippling “ . 3,544 “
“ “ “ ultimate “ . 4,463 “
“ “ show 178 per cent. higher crippling strength.
“ “ “ 183 “ “ ultimate “

NOTES AND COMMENTS.

LITERATURE.

Notes on Mechanical Laboratory Practice by C. H. Benjamin, Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

This work is an embodiment of the essentials of the means, material, and machine used in testing materials directly connected with mechanical engineering. Professor Benjamin has introduced a routine or system for the laboratory, which in itself is highly commendable; for, the quicker a student is taught systematic practice, the more readily will he fall into line, when no longer under a Professor, but rubbing against the unsympathetic competition of the world. While designed for the use of students, it is also invaluable for the professional man, as a book of reference. The book is well printed on good paper, and the various appliances mentioned in contents below clearly illustrated.

CONTENTS.

Chapter I.—The Strength of Materials.—The testing machine. Extensometers and other measuring instruments. Forms of specimens. Routine for various tests and forms for reports.

Chapter II.—Dynamometers.—Absorption and transmitting dynamometers. Alden dynamometer. Webber dynamometer. Belt-testing machine. Calibration of dynamometers. Directions for use and forms for reports.

Chapter III.—Measurement of Heat and Steam.—Thermometers, pyrometers, draft, and steam gauges. Calibration of apparatus. Barrel calorimeter. Throttling calorimeter. Separating calorimeter. Barrus calorimeter. Forms for reports.

Chapter IV.—The Testing of Steam Boilers.—Equivalent evaporation. Table of factors. Standard method of making a boiler test. Simple forms for ordinary trials.

Chapter V.—Indicators and Planimeters.—Directions for the care of indicators and their calibration. Reducing motions. Directions for the use of indicators. Theory of the polar planimeter and directions for its use. Indicator diagrams.

Chapter VI.—Testing Steam Engines.—Instruments. Test of surface condenser. Directions for making an engine test and forms for reports. Standard method for duty trials of pumping engines. Testing small pumps. Tables.

DIGEST OF PHYSICAL TESTS.

[For the convenience of the readers of the DIGEST OF PHYSICAL TESTS we have arranged below a list of treatises and notes that have appeared in many of the leading mechanical newspapers and magazines during the year 1896. The titles and dates of the papers containing the articles, and names of the writers, are given when they could be obtained. Although some of the above-referred-to articles are very short, and may prove of little value, still the list embraces contributions large and small, and will doubtless prove of advantage for ready reference.—EDITOR.]

APPENDIX A.

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OPINIONS OF THE PRESS.

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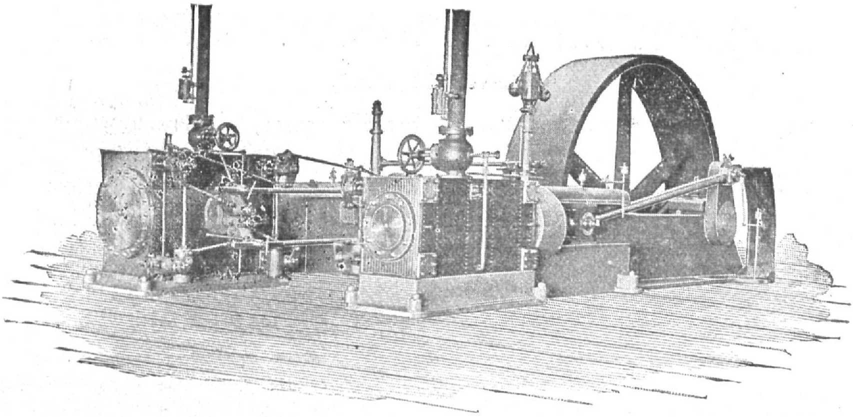

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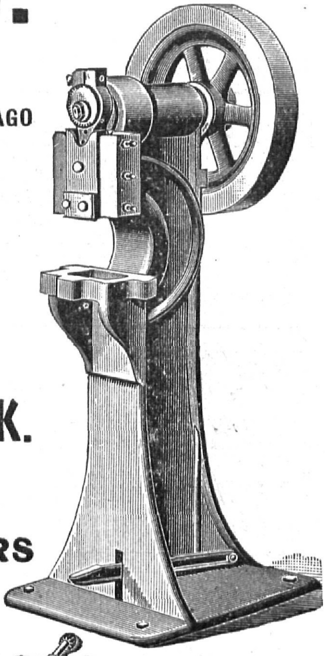

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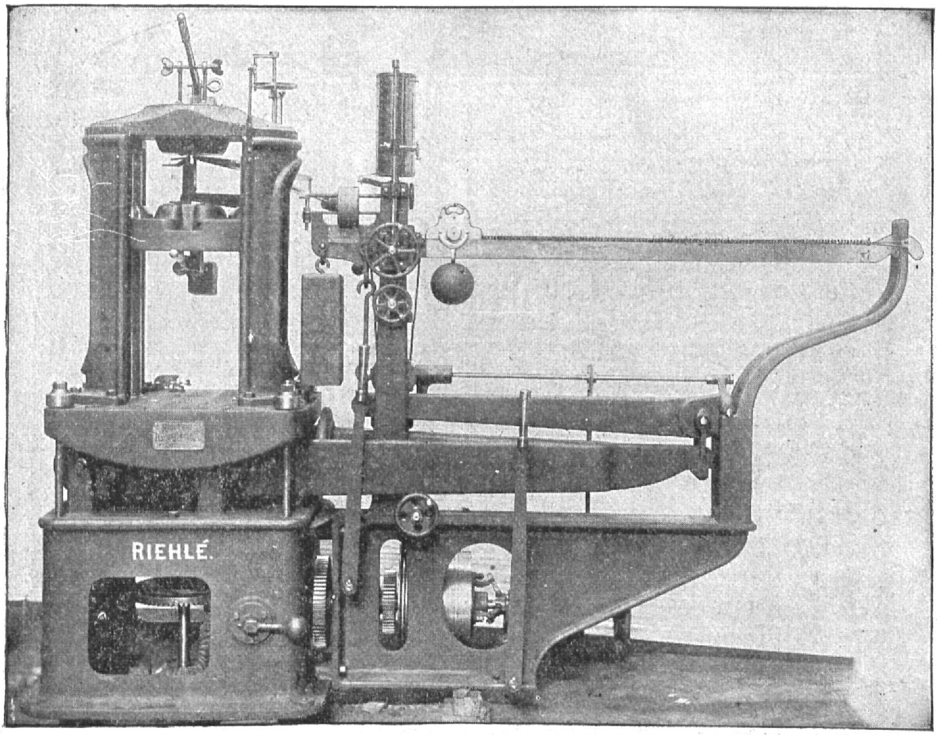

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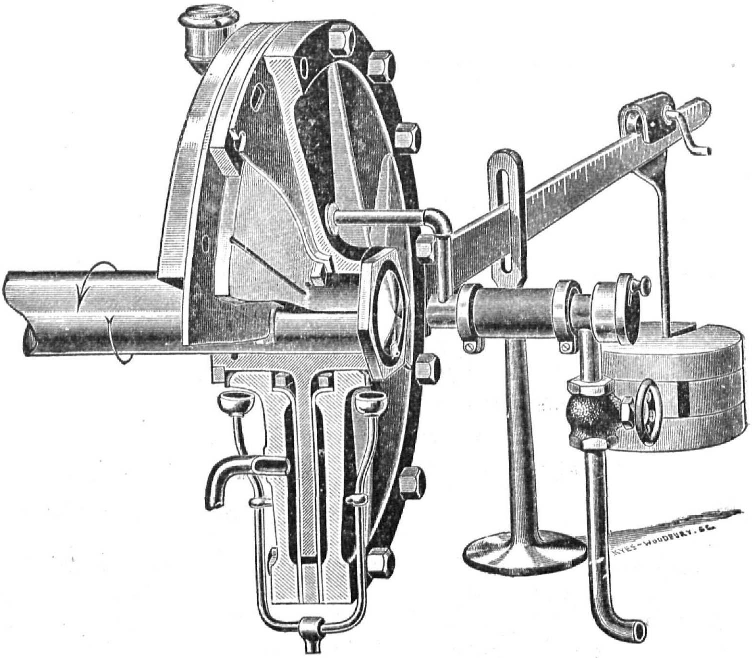

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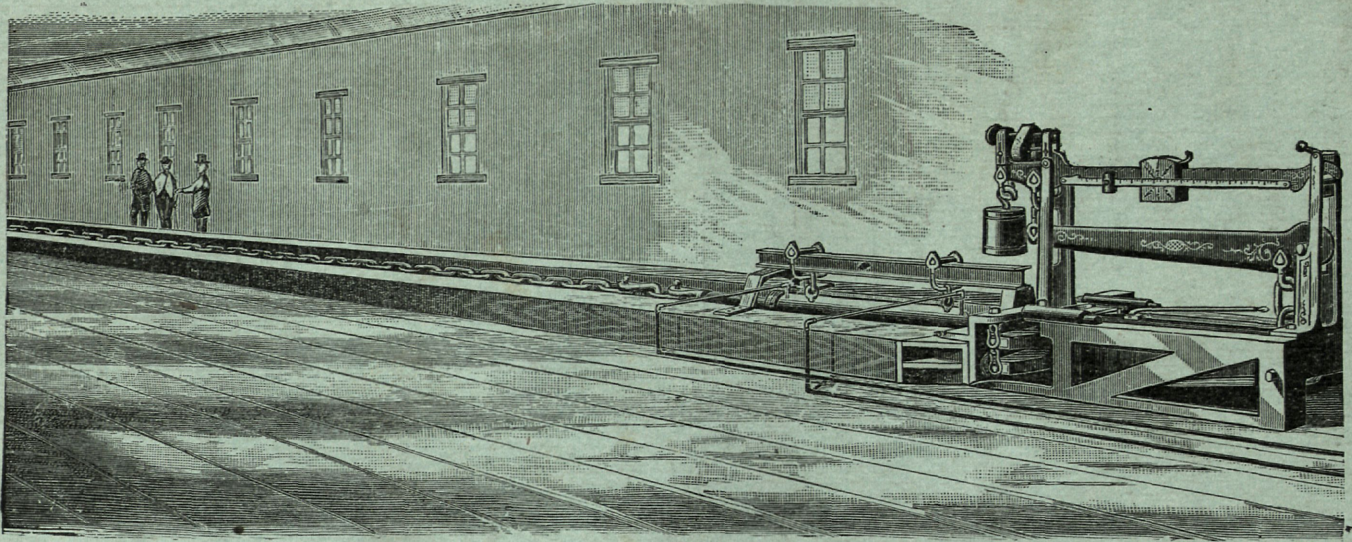

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